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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

EUGENE S. McCARTNEY

WILLIAM C. STEERE

VOLUME XXVIII (1942)

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— Seneca, *Naturales Quaestiones*

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NOTES ON HAWAIIAN FUNGI

ERNST A. BESSEY

OVER a large portion of the area of the Hawaiian Islands the fungous flora has undergone beyond doubt a very great change, although this cannot be demonstrated by comparison of earlier mycological collections with those more recent. The islands arose as a result of volcanic action in the floor of the Pacific Ocean at a depth of over three miles and at a distance of about 2,500 miles from the nearest continent. The first human settlements, so far as can be estimated, were made between 800 and 1,300 years ago by Polynesians coming in their outrigger boats from Tahiti or other island groups 2,000 to 2,500 miles distant. They brought with them pigs, dogs, and chickens and, as hitchhikers, rats, as well as coconut (*Cocos nucifera*), taro (*Colocasia antiquorum* var. *esculenta*), sweet potato (*Ipomoea batatas*), banana (*Musa spp.*), a small variety of sugar cane (*Saccharum officinarum*), and perhaps a few other plants. Neither the animals nor the plants they introduced had much effect upon the indigenous flora that had developed in the course of the millions of years since the islands had emerged from the depths of the sea.

When in 1778 Captain Cook found the Hawaiian Islands they were covered with their native vegetation, except for the numerous small fields planted to the introduced plants mentioned above and an occasional tree cut for use as timber or for making a canoe. There were no grazing animals, and the original cover of vegetation was practically undisturbed. By 1795 or a little later the whites had introduced horses, cattle, sheep, and goats, whose grazing rapidly led to the extermination of most of the native herbaceous plants and a large part of the shrubs and young trees in all accessible locations. Erosion of the denuded slopes and plains became very great. To make matters worse, the guava (*Psidium guajava*) and lantana (*Lantana camara*) were introduced and spread with great rapidity, soon covering the areas denuded by the grazing animals and crowding out

more of the native plants. Sod-producing grasses were brought in, such as Bermuda grass (*Cynodon dactylon*), Johnson grass (*Sorghum halepense*), and St. Augustine grass (*Stenotaphrum secundatum*), which assisted in the extermination of the few remaining native plants. The result is that until one goes into the hills to an altitude of 1,200 to 1,500 feet, and sometimes much higher, he sees only exotic vegetation. Even on the higher hills hundreds of species of woody plants have been introduced, so that only near and on the mountain tops is it possible to find pure stands of the original flora. This is especially true of Oahu Island.

The first collections of fungi were only incidental to those of vascular plants made by visitors to the islands in the first hundred years of the white man's knowledge of them. In 1895 A. A. Heller collected extensively, preparing for distribution several centuries of higher plants, and in addition picked up about two dozen species of fungi. Charles N. Forbes, botanist of the Bishop Museum in Honolulu for twelve or more years, made very numerous collections of higher plants, but also included (between 1910 and 1920) a good many of the higher fungi, some of which were identified by Dr. E. A. Burt (1), of the Missouri Botanical Garden. In 1921 Dr. F. L. Stevens spent four and one-half months on a Bishop Museum fellowship, principally upon the island of Oahu, but also visiting several other islands. He was particularly interested in the fungi that grow superficially, Meliolaceae, Capnodiaceae, etc., as well as in rusts, smuts, and a number of the smaller parasitic Pyrenomycetes. His report on his and earlier collections was published in 1925 (5). In the winter of 1927–28 Dr. C. L. Shear and Dr. Neil E. Stevens, of the United States Department of Agriculture, spent some months in the Territory, giving their attention chiefly to the Ascomycetes. The present writer was visiting professor of botany at the University of Hawaii from September, 1939, to June, 1940, and collected numerous specimens. Probably the most intensive studies of fungi have been made by Dr. H. L. Lyon and others of the staff of the Experiment Station of the Hawaiian Sugar Planters' Association and by the plant pathologists of the Hawaiian Experiment Station and of the Pineapple Producers Cooperative Association. As a result sugar cane, pineapple, and other economic plants have long lists of fungi that are found upon them as parasites and saprophytes. It should be noted that almost without exception these hosts are introduced plants. No

such study has been made of the fungous flora of any of the truly endemic Hawaiian plants. The slime molds, usually included among the fungi but almost certainly with no good reason, were the subjects of investigation by Dr. O. N. Allen, of the Department of Botany of the University of Hawaii. Dr. G. K. Parris, of the same institution, has published a check list and host index (4) of all the reported species of fungi from the region, a total of 729 species and varieties, including 99 slime molds.

It is very noticeable that the exotic woody plants, except those extensively cultivated, are usually freer from fungi than the native plants. Thus the native Metrosideros in the forests at the higher elevations is shown by Parris to have sixteen species of fungi, while the introduced and widely grown Eucalyptus has only six species, and the genus Casuarina, which is very widely planted, has no recorded fungi. The Hawaiian species of Acacia are credited with eleven fungi, and the closely related American Prosopis has but six. It is different when native and introduced herbaceous plants are compared, for the former have been driven back into the mountains and have not been examined for their fungous parasites as thoroughly as the latter species of the lower areas, since these include very many economic species or plants grown for ornamental purposes.

Turning now to the various groups of fungi, we find that many orders are not at all or only scantily represented among the reported fungi. Doubtless much of this apparent dearth of species in some groups is due more to lack of intensive search than to their actual absence. Thus the Chytridiales (in the older, wider, usage of the term) are represented by only two species, found in introduced cultivated plants, *Rhizidiocystis ananasi*, which kills the root hairs of the pineapple (*Ananas comosus*) and a suspected but unnamed fungus found by C. W. Carpenter (2) in the tissues of the stalks of sugar cane (*Saccharum officinarum*). In view of the widespread occurrence of members of this order in soil and water in temperate and tropical regions it is probable that it is actually better represented in Hawaii than the foregoing list would indicate. However, all the soil samples collected by the writer had to be fumigated before leaving Honolulu, and they did not reveal any chytrids when studied by Dr. F. K. Sparrow, of the University of Michigan. Of the Saprolegniales two species were trapped by the author by using sterile hemp seeds: *Achlya prolifera* and *Dictyuchus sterilis*. Since only a

few attempts were made to find these fungi they may well be more abundant. In the Peronosporales numerous species of Pythium and Phytophthora have been isolated and identified by the plant pathologists studying the various introduced economic plants. Only two Peronosporaceae have been reported: *Pseudoperonospora cubensis* on muskmelon (*Cucumis melo*) and cucumber (*C. sativus*) and *Peronospora effusa* on spinach (*Spinacia oleracea*), these three being introduced economic hosts. Two species of Albugo are known: *A. ipomoeae-panduranae* on an upland species of morning-glory (*Ipomoea indica*), but not on the sweet potato (*I. batatas*), and *A. candida* on cabbage and related Brassica species. The very abundant *Portulaca oleracea* is not attacked by *A. portulacae*, which is common on the North American mainland. Two species of *Entomophthora* have been reported, to which must be added *E. sphaerosperma*, found in 1940 on an introduced insect, *Pycnoderes quadrimaculatus*.

The Ascomycetes demonstrate how the special interest in particular families, as well as the conspicuousness of the specimens, leads to unevenness in the knowledge of the group as a whole. Dr. Roland Thaxter was interested in the Laboulbeniales and, without visiting Hawaii himself, made an intensive study of available collections of Hawaiian insects, with the result that he recognized six species of the genus Laboulbenia. The Xylariaceae are conspicuous fungi and, consequently, have been collected frequently. Dr. Shear and Dr. Neil E. Stevens were interested in the smaller Pyrenomycetes and found Diaporthe and related genera in abundance. Dr. F. L. Stevens, with his interest in the Meliolaceae, Capnodiaceae, and other more or less superficial Ascomycetes, found one hundred species of them, of which seventy-four were previously undescribed, including twelve new genera. Practically all these novelties were limited to hosts endemic in Hawaii. Stevens listed only five Discomycetes, but Miss Edith Cash in 1938 added thirty-four more, all but four of which were obtained by Shear and Neil E. Stevens. The writer's own collections add four more species to the list, making a total of forty-three species now known from that region.

Although the drier parts of the territory would seem to be well suited for Tuberales none have been found so far, nor have any of the Taphrinales been observed. Only the conidial stages were observed of the Erysiphaceae, as is true of this family in most tropical regions.

Thirty-nine species of the Uredinales were recorded by F. L. Stevens. Of the seventeen species collected by the writer only three were not in Stevens' list.

The Heterobasidiae (excluding rusts and smuts) are very abundant, but the number of species is not great. Burt records three species of Auricularia; the collection of the author added seven, in the Tremellaceae and Dacrymycetaceae.

The Corticieae are very abundant, but the number of species is not large. The Hydnaceae are represented by Radulum and one or two stipitate, long-toothed species. No Boletaceae have been reported. Clavariaceae are not common. Polyporaceae are well represented by the common genera. The native *Acacia koa* is host to quite a number of species of this family. Agaricaceae are mostly represented by wood- and bark-inhabiting species. The ground-inhabiting species are found in large numbers on lawns, parks, roadsides, and similar places, where the introduced turf-making grasses are well developed. Only once has the writer seen a specimen on the ground of the forest, and that was near the edge, where the illumination was good. In the wet forests the fallen twigs and branches bear Agaricaceae in fair abundance after a series of rains, but they do not occur on the ground. The ground is not covered by a thick humus layer, as it is in the woods of Michigan. After several days' rain numerous minute Marasmii, Pleuroti, and other agarics appear on the bark of various trees and on the reticulate leaf sheaths of the coconut, as well as on sugar-cane trash in the fields.

Gasteromycetes are not very common. A few species of Lycoperdon, Geaster, Mycenastrum, and similar genera were reported by Burt. *Phallus rubicundus* was reported by Cobb on sugar-cane roots over thirty years ago. To these the author has added a few others, including an apparently undescribed species of Pseudocolus. Tylostoma has been found by C. N. Forbes in drier portions of the Territory. It would seem probable that some of the genera characteristic of the dry regions of southern California, Arizona, and New Mexico may be found, but to determine this point will require a greater number of mycologists than now are available in Hawaii.

The Fungi Imperfecti are everywhere. Yet it is noticeable that a large number of species of higher plants are not found as hosts of any parasitic species of this group. Forms of Gloeosporium and Colletotrichum occur on injured and dying leaves of native and intro-

duced plants. In some cases they appear to be active parasites, but more often they are saprophytic or merely feebly parasitic on weakened tissues. The genera Septoria, Phoma, Phyllosticta, and Cercospora, among the strict parasites, are those in which the greater number of species occur. The common Penicillia and Aspergilli of world-wide distribution are found in abundance. A number of more strictly tropical Imperfect Fungi occur, but need further study.

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FURTHER STUDIES OF INHERITANCE OF VARIEGATION IN PETUNIA: BROKEN-VARIEGATED

ERNEST E. DALE

TWO types of flower variegation have thus far been reported in petunia: a mosaic form, by Malinowski and Sachsowa (1916, and Malinowski and others in later papers), and a reversible type, by Dale (1941). A variegation designated "stippled," by Dale (1942) appears to be the same as the mosaic type of Malinowski and Sachsowa. Crosses between the present variegation and "reversible" and "stippled" demonstrate that "broken-variegated" is a distinct genetic type. There are also ornamental varieties of the garden petunia with blotched, white and colored flowers, which are commonly called "variegated." Such strains studied by Malinowski (1914), Ferguson (1932), Harder (1934), Schröder (1934), and Levan (1939) do not have the mosaic character usually associated with variegation, and these unstable patterns, if they are to be considered variegations, are clearly of a special type. Indeed, the studies of both Harder and Schröder indicate that pattern development in these types is associated with temperature and light conditions. The blotched flowers appear to be transitional forms, the direction of change being environmentally controlled.

A strain of *broken-variegated* was obtained from Dr. W. C. Steere in 1929. Since that date variegated plants have been found twice in Michigan. One plant was discovered in a private garden near Ann Arbor, in 1933; the other came from a garden within the city, in 1935. In addition, a strain of petunia with green-edged flowers has occasionally produced broken-variegated plants. Intercrossing has shown that the variegation in these four strains is genetically identical. Since the variegated type has not, to the author's knowledge, been offered for sale by seed houses or grown as an ornamental its sporadic occurrence suggests either recurrent mutation or, possibly, some complex kind of segregation.

A flower of the broken-variegated type is illustrated in Plate I, Figure 1. Early in the season the flowers may have much less spotting than those borne later on the same plant. The combination of variegated and self-colored flowers growing side by side on different branches of the same plant, which is a striking feature of many variegations, does not occur in the broken-variegated strain, nor have self-colored plants been obtained from inbred seed of this type.

Routine counts of the chromosomes in pollen mother cells gave $n = 7$ in both *broken-variegated* and *green-edged.* These counts included observations of both anaphase groups of meiosis I for the variegated type. The aceto-carmine smear technique was used.

In crosses *broken-variegated* was recessive to both *white* and *colored.* Segregation in the F_2 and backcross differed markedly, depending upon whether the crosses were carried out in pink or purple strains (see Table I).

The results shown in Table I are so variable that it is worth noting that the data are from reciprocal crosses. Family 1472 clearly suggests recessive monohybrid segregation. The only other significant conclusion to be drawn from the table is that all the remaining families gave much lower proportions of *variegated* than would be expected on the basis of monogenic inheritance. This raises the question whether the results could be due to disturbed monogenic segregation resulting from some kind of modifying factors in the strains used. Accordingly, new crosses were made with a variegated, purple-flowered variety and a purple, self-colored strain. The F_2 and backcross data are given in Table II.

The F_2 and one backcross family conform to expectation for recessive monogenic inheritance, but one backcross family, 1771, departs significantly from expectation, the deviation being approximately three times the standard error. It is to be observed that the total figures for the backcross lie well within expectation for monogenic segregation. Since 1771 and 1779 are from reciprocal crosses and since the F_2 conforms so very closely to the expected proportions, it seems reasonable to conclude that *broken-variegated* is inherited as a monogenic recessive.

As mentioned earlier, a strain of petunia with green-edged flowers occasionally gave rise to broken-variegated plants. This form is illustrated in Plate I, Figure 2. All green-edged flowers, whether variegated or nonvariegated, are much reduced in size as

TABLE I

F_2 AND BACKCROSS SEGREGATION OF THE CROSS PINK, BROKEN-VARIEGATED × PINK, SELF-COLORED IN PETUNIA

F_2 GENERATION

Family number	Self-colored	Broken-variegated	Standard error
1472	75	19	
1475	90	3	
Total	165	22	4.4
Expected	140	47	
Backcross			
1497	42	20	
1498	22	5	
1518	24	6	
1520	39	1	
Total	127	32	5.0
Expected	79.5	79.5	

TABLE II

F_2 AND BACKCROSS SEGREGATION OF THE CROSS PURPLE, BROKEN-VARIEGATED × PURPLE, SELF-COLORED IN PETUNIA

F_2 GENERATION

Family number	Self-colored	Broken-variegated	Standard error
1764.2 *	37	12	3.0
Expected	37	12	
Backcross			
1771	125	84	7.0
1779	192	203	9.9
Total	317	287	12.3
Expected	302	302	

* The reciprocal cross did not produce viable seed.

compared with normal (nongreen) types. The history of the sporadic occurrence of such variegated plants is shown in Table III.

TABLE III

THE OCCURRENCE OF BROKEN-VARIEGATED PLANTS IN INBRED FAMILIES OF GREEN-EDGED IN PETUNIA

Family number	Year grown	Green-edged nonvariegated	Green-edged broken-variegated
776	1932	31	0
1169	1935	32	0
1326	1936	3	0
1327	1936	20	1
1454	1937	19	1
1587	1938	18	1
1604	1938	19	1
1697	1939	8	0
1792	1940	10	0
1841	1941	10	0

All the families of Table III were inbred, but the green-edged strain traces back to a cross between two green-edged plants which came from different sources. It is entirely possible that broken-variegated plants may have occurred in families 776 and 1169 and have been overlooked. For not until later did the author realize that *green-edged* occasionally segregated out the variegation, and 776 and 1169 were not specifically checked for variegations.

Crosses between the sporadically produced *green-edged, variegated* and the ordinary *broken-variegated* gave all broken-variegated progeny. When crosses were made between *broken-variegated* and *green-edged* (*nonvariegated*) the results shown in Table IV were obtained.

Since *broken-variegated* and *green-edged* are both recessive to *normal*, it was to be expected that all the F_1 progeny would be *self-colored*. The occurrence of variegation in the progeny shows that a factor for *broken-variegated* was contributed by the green-edged parent. Only one family, however, 1375, has a ratio approaching the 1 : 1 expected if the green-edged parent was heterozygous. It may be noted that the number of progeny indicates reduced fertility in this family.

Three pairs of reciprocal crosses are represented in the data of Table IV. Thus it is evident that a factor for variegation (from

TABLE IV

SEGREGATION IN THE F_1 GENERATION OF THE CROSS BROKEN-VARIEGATED × GREEN-EDGED IN PETUNIA

Family number	Flowers self-colored	Flowers broken-variegated
1375	5	7
1377	38	11
1617	39	11
1630	43	7
1719	48	6
1722	42	7
Total	215	49

green-edged) was readily transmitted through both the pollen and the ovules. It is possible that the green-edged parent may have been homozygous for the variegation factor. But this would require some kind of unstable suppressor mechanism which would normally prevent the expression of *variegated* in *green-edged* and would also occasionally give rise to variegated plants. How such a mechanism could operate the author is unable to explain.

The direction of change in *broken-variegated* is typically from dark- to light-colored. Anthocyanin in petunia flowers is borne in the floral epidermis. Since the broken-variegated plants do not segregate out self-colored flowers or produce self-colored from seed, the evidence suggests that somatic change in this type is phenotypical. But the possibility is not excluded that we are dealing with a genotypical variegation with mutation limited to the epidermal cells.

SUMMARY

1. In petunia broken-variegated flowers showed recessive monogenic inheritance in purple-flowered strains, but in pink-flowered strains gave wide departure from expectation.

2. A strain of petunia with green-edged flowers has occasionally segregated out broken-variegated plants.

3. Crosses between *broken-variegated* and *green-edged* gave about 19 per cent of *broken-variegated* in F_1.

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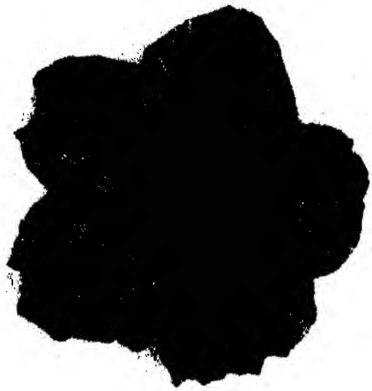

FIG. 1. *Broken-variegated* type of petunia flower

FIG. 2. Green-edged *broken-variegated* petunia flower

STUDIES ON PHILIPPINE CHLOROPHYCEAE. I
THE DASYCLADACEAE *

WILLIAM J. GILBERT

MEMBERS of the Dasycladaceae have been among the least reported of Philippine Chlorophyceae. According to the present knowledge of the writer, the first record of a plant of this family from the Philippines is that of *Polyphysa spicata* Kützing by Dickie (1876), the material having been collected at Mactan on the "Challenger" expedition. According to Solms-Laubach (1895, p. 31), in his "Monograph of the Acetabularieae," this was an incorrect determination, for he lists the same material under *Halicoryne Wrightii* Harvey, not *H. spicata* (Kützing) Solms-Laubach. A year later Dickie (1877) reported a collection of *Acetabularia Calyculus* Quoy & Gaimard from the harbor of Cebu. In 1913 Weber–van Bosse, in the first part of her *Liste des algues du Siboga,* cited both *Bornetella sphaerica* (Zanardini) Solms-Laubach and *B. oligospora* from the Sulu Archipelago. From then until 1932 there were no further definite records, but in that year Howe (1932) listed *A. major* Martens from Panay Island. There seems to be no other record of Philippine Dasycladaceae except a rather indefinite report of an Acetabularia by Solms-Laubach (1895, p. 23), who writes of seeing photographs of specimens of a plant that were "in Herb. Sloane sub 163, fol. 2, and 223, fol. 36," collected by Kamel in Luzon, and named *Androsaces Luzonis.* Because he had only photographs of the plant it was not possible to identify the species definitely, but Solms-Laubach indicates that it would seem to be either *Acetabularia major* Martens or *Acetabularia Gigas* Solms-Laubach.

The sources of material included in this study are largely the same as those mentioned in a previous paper by the author (Gilbert, 1942), except for the addition of a large number of specimens which

* Papers from the Department of Botany of the University of Michigan, No. 803.

were collected (in January and February, 1941) either by or under the direction of Professor H. H. Bartlett, of the University of Michigan, with the coöperation of the Zamboanga Office of the Philippine Bureau of Fisheries, through the interest and kindness of the chief, Mr. José Domantay. These were supplemented by material collected at Basilan Island by Mr. Liborio Ela Ebalo, of the Department of Botany, University of the Philippines.

Ten species of Philippine Dasycladaceae are discussed here. With the addition of *Acetabularia Calyculus*, which has been previously reported but is not found among the present collections, the number of species of Dasycladaceae from the Philippines is brought to eleven, six more than were previously known from this region. The species fall into five genera, two of which (Neomeris and Cymopolia) have not before been listed from the Philippines. A new species is proposed in Acetabularia. Of the ten species discussed in this paper the following are recorded from the Philippines for the first time: *Neomeris van-Bosseae*, *N. annulata*, *Cymopolia van-Bosseae*, *Bornetella nitida*, *Acetabularia dentata*, and *A. philippinensis*.

Systematic Account

The thallus of plants included in the Dasycladaceae is coenocytic (except during part of the life cycle of Acetabularia) and consists of a large, much-elongated, nonseptate, simple or, rarely, branched axial cell, which is attached to the substratum by means of rhizoids and which has numerous successive whorls of articulated, simple or ramified, lateral branches of determinate growth, that frequently bear deciduous hairs at their tips. The lateral branches may be modified in various ways, and in them or in structures to which they give rise gametes are formed directly or aplanospores are produced that are later transformed into gametangia. Zoospores and akinetes are unknown. Chromatophores are small, elliptical to lenticular, containing a single pyrenoid.

KEY TO THE GENERA

A. Lateral branches all of one kind, bearing 2 or more branchlets at their tips
- **B.** Aplanosporangia borne singly and terminally on primary branches between sterile branchlets .... **Neomeris, p. 17**
- **B.** Aplanosporangia borne laterally on primary branches, 1 or more per branch .... **Bornetella, p. 21**

A. Lateral branches of two kinds; all branches in a whorl of either the one or the other type
  B. Aplanosporangia borne singly at tips of fertile primary branches between branchlets; sterile branches simple and restricted to whorls clothing constricted parts of central axis .... Cymopolia, p. 19
  B. Aplanosporangia produced by transformation of simple lateral primary branches; sterile branches always forking, not simple
    C. Whorls nearly covering axis, a whorl of sterile branches alternating with a whorl of fertile branches throughout .... Halicoryne, p. 27
    C. Lateral-branch whorls restricted to upper part of axis, usually being sterile except for a single terminal whorl of fertile branches often united in a disclike structure .... Acetabularia, p. 29

NEOMERIS Lamouroux, 1816

These are calcified plants which are subcylindrical, clavate or subfusiform, consisting of a simple erect nonconstricted elongated axis that bears many closely set whorls of compound branches, each branch composed of a basal segment that gives rise at its tip to a stalked sporangium and 2 sterile branches which are inflated at their distal ends, with the swollen tips laterally coherent and forming a cortex; each of these cortical branches bears a deciduous branching hair at its tip. A calcareous capsule encloses each sporangium; it may or may not be coherent with adjacent capsules.

A. Calcareous capsules of sporangia not laterally coherent; fruiting portion not appearing annulate .... 1. *N. van-Bosseae*, p. 17
A. Calcareous capsules of sporangia coherent, thus giving plant an annulate appearance in fruiting area...................... 2. *N. annulata*, p. 19

1. *Neomeris van-Bosseae* Howe

Howe, 1909, p. 80, pl. 1, figs. 4, 7, pl. 5, figs. 17–19; Weber-van Bosse, 1913, p. 88; Setchell, 1926, p. 80.

The plants are gregarious, 1.0–2.4 cm. high and 1.5–3.0 mm. broad, subcylindrical to clavate, sometimes subfusiform, often curved near or above the middle. The erect axis gives rise to many successive whorls of primary branches, each whorl containing 30–40 branches, and each branch bearing at its terminal end a stalked sporangium and 2 secondary branches with capitate ends which are laterally coherent and which thus form the cortex. The branches of the first order are 350–710 μ long and about 34–51 μ broad in the lower half. The sporangia, including the stalks, are 180–200 μ long and contain a single globose oval spore 136–170 μ long and 120–

160 μ wide when mature. The thick calcareous coats around the sporangia are not laterally coherent, so that the sporangia are free from one another. Each branch of the second order bears at its tip a single branched septate deciduous hair. At the top of the thallus these hairs are not deciduous, but form a persistent apical tuft.

Distribution. — Malay Archipelago, Friendly Islands, Tahiti, Hawaii.

Collections. — *Curran, Forestry Bureau 11124*, Tayabas Province, Luzon, April. *Shaw 1151* and *1165*, Lamao, Province of Bataan, Luzon, May. *Velasquez 746*, west shore of *muelle*, vicinity of Puerto Galera, Mindoro, March; *851*, Medio Island, near Puerto Galera, Mindoro, April; *910*, Paniquian Island, vicinity of Puerto Galera, Mindoro, April; *1021*, San Teodoro Municipality, vicinity of Puerto Galera, Mindoro, April.

The material seems to agree very well with Howe's excellent description of *Neomeris van-Bosseae* (Howe, 1909, p. 80), the one significant difference being in the length of the first order of branches. At first the only materials at hand for study were the collections of Velasquez cited above, and it was noted in one collection (*Velasquez 910*) that, although the plants were mature, the length of the first order of branches varied from 350 to 430 μ, being much shorter than the 570–1000 μ ones in Howe's description; also, the plants appeared more slender than those with longer primary branches, though they still remained within the ratio of length to width which Howe has indicated for *N. van-Bosseae*. It was then decided that the difference in length of the first order of branches was not of form or varietal significance, for intermediate lengths were found on other specimens. It was interesting, therefore, to remark, sometime later, that Howe had called attention to a collection of *N. van-Bosseae* from Lamao, Bataan Province, the Philippines (*Shaw 1165*), with the following penciled note: "Much smaller than typical specimens and primary branches only 350–500 μ long; secondaries occasionally in 3's; but apparently not well separable from *Neomeris van-Bosseae*." Although the writer has not been able to find the secondary branches in threes, the specimens in *Velasquez 910* appear almost identical with those of the Shaw collection. It is apparent, therefore, that in *N. van-Bosseae* the primary order of branches may be considerably shorter than those previously described.

2. *Neomeris annulata* Dickie

Dickie, 1874, p. 198; Solms-Laubach, 1893, p. 62, pl. 8, figs. 1, 3–4, 7, pl. 8b, figs. 8, 12–13, 17; Børgesen, 1908, p. 272, figs. 1–2; Howe, 1909, p. 87, pl. 1, fig. 2; Weber–van Bosse, 1913, p. 88; Yamada, 1934, p. 51, figs. 16–17; Tseng, 1936, p. 158, fig. 19.

The plants are either gregarious or scattered, 9–15 mm. high and 1–2 mm. broad, subcylindrical or fusiform. The thallus consists of an erect simple axis giving rise to many successive whorls of branches; the branches number about 38–44 per whorl and each bears at its terminal end a stalked sporangium and 2 branches of a second order that have capitate ends which are laterally coherent, thus forming the cortex. The arrangement of these secondary branches is such that there are twice as many transverse rows of facets in the cortex as there are whorls of primary branches. Each branch of the second order bears at its tip a branched septate deciduous hair. The branches of the first order are 220–290 μ long and 12–16 μ wide in their lower parts. The sporangia, including the stalks, are 160–185 μ long and 54–74 μ broad; they contain a single oblong to obovoid spore 122–140 μ long and 45–70 μ broad. The sporangia are strongly calcified, and the thick coating around the spores is coherent with the capsules of groups of other sporangia, so that characteristic interrupted calcareous transverse rings are formed in the fruiting parts.

Distribution. — Bermuda, Florida, West Indies, Indian Ocean, Malay Archipelago, China Sea (Hainan), Friendly Islands.

Collections. — *Velasquez 746a*, west shore of *muelle*, vicinity of Puerto Galera, Mindoro, March; *910a*, Paniquian Island, vicinity of Puerto Galera, Mindoro, April.

Each of the collections above is represented by a single specimen found mixed with *Neomeris van-Bosseae* in two of the collections cited under that species, namely, *Velasquez 746* and *910*. The two specimens were removed from those collections, transferred to different envelopes, and designated *Velasquez 746a* and *910a*, respectively. The material agrees well with the more complete descriptions of Howe (1909, p. 87) and others.

CYMOPOLIA Lamouroux, 1816

These are plants with a simple or branching thallus made up of a series of calcified, more or less moniliform segments connected by a

series of uncalcified "internodes." The calcified segments consist of an elongated central axis (running the whole length of the plant) that gives rise to a number of successive whorls of branches, each branch bearing at its top a sessile sporangium and several corticating branches. The corticating branches extend beyond the sporangia and have capitate ends that are more or less coherent, thus providing a covering for the sporangia and forming a unistratose cortex. Between the calcified segments the axis is constricted and gives rise in this region to several successive whorls of short simple sterile branches. Branching of the axis takes place in this uncalcified portion. The thallus is terminated by a tuft of branched hairs.

Cymopolia van-Bosseae Solms-Laubach

Solms-Laubach, 1893, p. 78, pl. 8b, figs. 9–10, 15–16; Weber-van Bosse, 1913, p. 89; Yamada, 1934, p. 52, figs. 18–19.

The thallus is simple, clavate, as much as 1.3 cm. in height although usually shorter, and segmented, the segments being 4–9 in number. Near the base of the plant the segments are about 1 mm. broad and 1 mm. long; they increase in size toward the top of the plant, so that the upper ones may reach 2 mm. in diameter and 1.3 mm. in height. The central axis is unconstricted for a short distance near the base of the plant, but constricted above, being 180–280 μ broad at the constrictions and 320–465 μ broad in the segments between the constrictions, usually with a greater diameter in the wider segments above. The central axis bears 8–18 successive whorls of fertile branches in each of the calcified segments, the number of whorls being only 8–12 in the lower segments. Each whorl consists of 17–26 branches. The primary or first order of branches are 184–450 μ long (the upper segments having the longer branches) and 20–54 μ broad; each gives rise at its terminal end to a single sessile sporangium and 4–9 corticating branches. The corticating branches are 198–312 μ in length and their capitate ends 54–68 μ wide, more or less coherent but separating rather easily after decalcification. In each of the internodes, between the calcified segments, there are 5 or 6 successive whorls of short simple sterile branches that are 84–136 μ long, numbering about 12–18 per whorl. The sporangia are globose or obovate, 170–240 μ long and 156–190 μ wide.

Distribution. — Malay Archipelago, Liu-kiu Islands.

Collection. — *Bartlett 14143*, Santa Cruz, Zambales Province, Luzon, May.

So far as the writer is aware, this is but the fourth record of this species in the literature. It has heretofore been reported in the Netherlands East Indies from Maumeri on the north coast of Flores Island (Solms-Laubach, 1893) and from several stations on the "Siboga" expedition (Weber–van Bosse, 1913). A third occurrence is recorded from the Liu-kiu Islands (Yamada, 1934). The detailed description above was occasioned by the fact that there seems to be no earlier morphological study that includes much more than the general features, measurements being given only for the height of the plant and the diameter of the sporangia. Yamada (1934, fig. 18) and Solms-Laubach (1893, pl. 8b, figs. 15–16) have produced two excellent habit sketches of the species. Weber–van Bosse (1913, p. 89) reports that the plant reaches a height of 1.5 cm.

This is the only species of Cymopolia found in Pacific waters, and it seems to be restricted to the region of the Malay Archipelago, southern Japan, and the Philippines, although the minuteness of the plant may have resulted in its being generally overlooked. It is to be readily distinguished from the only other known species of the genus, *Cymopolia barbata* (L.) Lamouroux, which is found in Florida, the West Indies, and the Canary Islands. The latter species reaches a height of 1–2 decimeters and branches; it differs also in the size of the corticating cells and sporangia and in the relative lengths of the simple sterile branches and the compound fertile branches, as well as in a number of other ways. Solms-Laubach (1893, pp. 78–79) has already given a good comparison of the two species.

BORNETELLA Munier-Chalmas, 1877

These are plants with globose or clavate, simple, more or less stipitate thalli. In structure they are composed of a central erect axis that gives rise to many successive whorls of long cylindrical branches which bear, laterally, from 1 to many aplanosporangia and which are terminated by 3–8 short inflated truncate branches that are laterally coherent and that form a unistratose cortex which is slightly calcified. When present, the stipe is the downward continuation of the central axis and branches irregularly at its lower end to form a small holdfast.

A. Thallus globose or oblong, 1 cm. or less in diameter .. 1. *B. sphaerica*, p. 22
A. Thallus subcylindrical to clavate, sometimes curved, 1.5–4 cm. long

B. One or 2 aplanosporangia formed on each primary branch; 8–60 spores per sporangium .... 2. *B. nitida*, p. 25
B. From 4 to many aplanosporangia formed on each primary branch, often crowded; 2–8 spores per sporangium ... 3. *B. oligospora*, p. 26

1. *Bornetella sphaerica* (Zanardini) Solms-Laubach

Neomeris sphaerica Zanardini, 1878, p. 38; *Bornetella sphaerica* (Zanardini) Solms-Laubach, 1893, p. 92, pl. 9, fig. 8; Weber-van Bosse, 1913, p. 90; *B. ovalis* Yamada, 1933, p. 277; 1934, p. 51, figs. 14–15.

The thallus is spherical or oval, often shortly stipitate, up to 1 cm. in breadth, although usually considerably smaller. The stipe, when present, reaches 1–2 mm. in length and branches irregularly below to form a small holdfast. The central axis is 0.5–1.0 mm. broad, cylindrical or slightly tapering to a rounded apex, extending about half the length of the frond, and bearing 11–14 successive whorls of long narrow cylindrical primary branches. There are in each whorl 14–22 primary branches 106–140 μ broad, increasing at their outer ends to 180 μ, and terminated by 4–7 short, capitate branches, the inflated ends of which are 284–500 (625) μ broad, truncate, laterally coherent, and calcified, making up a unistratose cortex. From 4 to 12 aplanosporangia are borne laterally on a primary branch, usually on the outer half of the branch, but sometimes scattered over the whole length; they are spherical, 210–300 μ broad when mature, and contain 4–16 aplanospores that are 94–136 μ broad and more or less spherical, with a slightly stratified wall about 5 μ thick (see Fig. 1 a–b).

Distribution. — Malay Archipelago, Liu-kiu Islands.

Collections. — *Villaflores 33*, Lubang Island, Province of Mindoro, Sept. *Balhani 772*, Sangig, Takut Tangug Bay, southwest of Matangal Point, east coast of Basilan Island, Jan.–Feb.

This interesting species is represented by two Philippine collections, which clearly show the spherical or ovoid thalli and the characteristic spherical sporangia and spores. *Bornetella sphaerica* cannot easily be told from *B. capitata* (Harvey) J. Agardh except in dealing with fruiting material, when a section through the thallus will quickly reveal which species is present, for *B. capitata* is characterized by oval or oblong sporangia and somewhat smaller, more or less ovoid, thick-walled spores (see Fig. 1 c–d). The writer has studied specimens of *B. capitata* from the Thousand Islands near Batavia, Java,

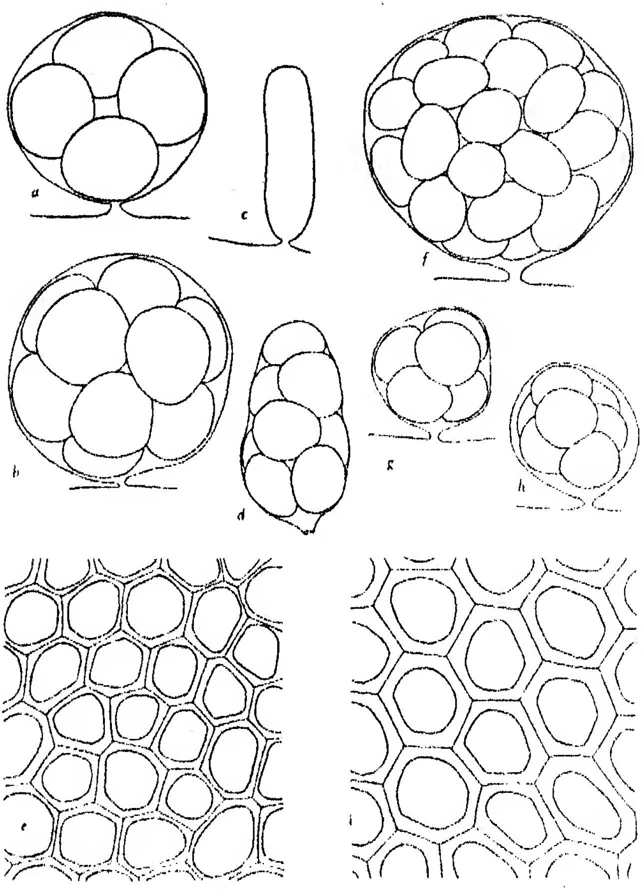

FIG. 1. *Bornetella spp.*: *a–b*, *B. sphaerica* (Zanardini) Solms-Laubach, aplanosporangia containing aplanospores, × 118. *c–d*, *B. capitata* (Harvey) J. Agardh; *c*, an immature aplanosporangium; *d*, a mature aplanosporangium; both × 118. *e–f*, *B. nitida* (Harvey) Munier-Chalmas; *e*, surface view of cortex after decalcification, showing the thickened ring of wall material in the radial walls of the cortical branches, × 54; *f*, a mature aplanosporangium, × 118. *g–i*, *B. oligospora* Solms-Laubach; *g–h*, mature aplanosporangia, × 118; *i*, surface view of cortex after decalcification, showing the thickened ring of wall material in the radial walls of the corticating branches, × 54

and wholly agrees with Weber-van Bosse (1913, p. 90) that it and *B. sphaerica* are different species. There is every reason to believe that *B. capitata* may also be found in the Philippines, even though it does not appear in the present material.

A question arises, however, as to the similarity of the Philippine specimens of *Bornetella sphaerica* to *B. ovalis* Yamada (1933, p. 277), the latter having been proposed as a different species from *B. sphaerica* on the ground that its thallus was shortly stipitate and that the aplanosporangia were produced on the upper part of the primary branches near the periphery of the thallus, whereas in *B. sphaerica* the frond was supposed to be sessile and the sporangia were generally distributed over the length of the primary branches. With regard to the first point, it is interesting to note that, although *B. sphaerica* was originally described as sessile, Solms-Laubach (1893, p. 90) has pointed out after studying a specimen of the original material that the specimen had apparently been carelessly collected and that the base was broken off, leaving a large opening into the lumen, so that, after drying, the material appeared to be sessile, a point which Yamada may have overlooked. One is impressed with the tenaciousness with which the holdfast clings to the corals on which this species grows, and often, unless one uses extreme care in collecting, the stipe is torn away from the main body of the thallus. So true is this of the Philippine material that only about one specimen in three has a short stipe; the other stipes were evidently broken off, and the fronds appear to be sessile. Upon careful examination one can see the torn lower end of the central axis in these "sessile" specimens, not to mention that there is a complete lack of any sort of attaching organs, the presence of which would be necessitated were the fronds actually sessile.

The other point of difference, the position of the sporangia, is only a minor one. It appears that in general most of the sporangia are borne on the upper part of the primary branches in *Bornetella sphaerica*, but at times intermediate conditions are evident in which the sporangia are pretty well spread along these branches. It is worth pointing out that the drawing of *B. sphaerica* in the paper by Solms-Laubach (1893, pl. 9, fig. 8), on which Yamada apparently based his opinion that the sporangia were generally distributed over the whole primary branch (not having seen any authentic ma-

terial himself), is described by Solms-Laubach as an "etwas schematisches Habitusbild" of a specimen, and does not claim to be wholly accurate. It seems probable then that *B. ovalis* Yamada should be considered synonymous with the previously described *B. sphaerica* (Zanardini) Solms-Laubach.

2. *Bornetella nitida* (Harvey) Munier-Chalmas

Neomeris nitida Harvey, 1857, List of Friendly Islands Algae, no. 83; *Bornetella nitida* (Harvey) Munier-Chalmas, 1877, p. 816; Cramer, 1891, p. 22, pl. 3; Solms-Laubach, 1893, p. 80; Weber-van Bosse, 1913, p. 89.

The thallus is subcylindrical to clavate, more often the latter; it is sometimes shortly stipitate, as much as 3.0 cm. high, 3–7.5 mm. broad, and, usually, curved. The central axis is 600–700 μ broad and more or less cylindrical, with a rounded apex; it extends nearly the whole length of the frond and is slightly constricted between the many whorls of long narrow cylindrical primary branches. The number of whorls varies greatly with the height of the plant, but appears always to be more than 60. Each whorl has 24–30 primary branches. These are 27–45 μ broad, increasing to 90 μ at their swollen terminal ends, where they give rise to 4–7 short capitate branches that are 110–240 μ broad. The thickened ring of the radial walls in the capitate branches is up to 20 μ thick, although it may be as much as 50 μ thick in the lowest part of the plant. These capitate branches are laterally coherent and calcified, and make up the cortex (see Fig. 1e). There are only 1 or 2 spherical aplanosporangia formed laterally on each primary branch; they are 160–320 μ broad when mature and contain 8–60 oval aplanospores 78–122(136) μ long and 57–68 μ wide, with a pitted wall 3–6 μ thick (see Fig. 1f).

Distribution. — Friendly Islands, Australia, Malay Archipelago.

Collection. — *McGregor 63*, Bohol Island.

It was at first with uncertainty that this collection was identified as *Bornetella nitida*, for although in most respects it seemed to agree well with material of that species there were one or two points of difference which were troublesome. It has previously been thought that in *B. nitida* the aplanosporangia were produced only singly on the primary branches, and indeed this was one among other reasons for separating from it *B. oligospora*, which has several

sporangia per primary branch. It was disturbing, therefore, to find 2 sporangia (though not more) on a number of the branches in the Philippine material. In addition, many of the sporangia on reaching maturity produced only 8–16 spores, in contrast to the 24–67 originally described for *B. nitida*.

Through the kindness of Dr. F. J. Seaver, curator of the Cryptogamic Herbarium at the New York Botanical Garden, the writer was able to borrow isotype material of *Bornetella nitida* (Harvey's Friendly Islands Algae, no. 83, sub *Neomeris nitida*) and was several times able to demonstrate the presence of a second sporangium on a primary branch. When only a single sporangium occurs it is regularly situated about 270–300 μ from the outer end of the branch; the second one usually develops farther in, near the middle of the branch. It is only seldom that both these sporangia are seen together on a branch, because the sporangia are very caducous, especially when mature. One must look for scars left by the sporangia, and these are usually more clearly perceived after the material has been boiled in a weak solution of potassium hydroxide. In addition, many of the sporangia in the Friendly Islands specimens produced only 8–16 spores (the usual number in the Philippine material), although many others produced the much larger number usually accredited to the species.

3. *Bornetella oligospora* Solms-Laubach

Solms-Laubach, 1893, p. 81, pl. 9, figs. 1–4, 6–7; Weber-van Bosse, 1913, p. 89.

The thallus is subcylindrical to clavate, sometimes slightly curved, up to 4 cm. in height and 4–6 mm. broad, occasionally shortly stipitate. The central axis is about 1.0–1.25 mm. broad, cylindrical, extending nearly the whole length of the frond, and not at all constricted between the whorls of branches. It gives rise to many successive whorls of long narrow cylindrical primary branches, numbering 27–32 per whorl. These branches are 70–100 μ broad, increasing to 120 μ in width at their terminal end, where they bear 4–7 short capitate branches, the inflated ends of which are 156–284 μ broad, with the thickened ring on the radial walls 30–58 μ wide. The secondary branches are laterally coherent, calcified, and form a unistratose cortex (see Fig. 1i). There are 4–12 spherical aplanosporangia produced laterally on each primary branch; they are

120–170 μ broad when mature and contain 2–8 oval to spherical aplanospores. The spores are 55–100 μ broad, with a pitted wall that is 5–10 μ thick (see Fig. 1g–h).

Distribution. — Malay Archipelago.

Collection. — *Merrill 9153*, Taytay, Palawan, April.

So much alike from an external view are *Bornetella oligospora* and *B. nitida* that it is scarcely possible to tell them apart unless a microscopical examination of their internal anatomy is made. In mature plants *B. nitida* has only 1 or 2 sporangia per primary branch, borne on the outer part of the branches; these sporangia are larger and produce more spores than the numerous, smaller, more generally distributed sporangia of *B. oligospora.* It is observed also that the very young sporangia of *B. nitida* are somewhat oval, in contrast to the young spherical sporangia of *B. oligospora.* Another apparently quite constant character separating the species is the width of the thickened ring in the radial walls of the cortical branches, the ring being 30–58 μ wide in *B. oligospora* and 10–25 μ wide in *B. nitida.* In *B. nitida* the calcification seems to be less heavy and the surface of the thallus less shiny than in *B. oligospora.*

HALICORYNE Harvey, 1859

These plants are calcified, clavate, and have a simple erect axis on which are produced many whorls of branches of two types, a whorl of sterile branching tufted hairlike branches alternating with a whorl of simple, sporangial, pod-shaped vesicular branches. The fertile branches are usually imbricate and cut off from the erect axis by a thin basal wall; on the upper side, not far from the axis, they bear a small protuberance, separating the upper aplanospore-bearing portion from the more or less cylindrical base. The spore membranes are thick and heavily calcified.

Halicoryne Wrightii Harvey

Harvey, 1859, p. 333; Dickie, 1876, p. 243 (as *Polyphysa spicata*); Agardh, J., 1886, p. 159, pl. 5, figs. 1–5; Cramer, 1895, p. 18, pl. 1, figs. 1–9; Solms-Laubach, 1895, p. 31, pl. 4, figs. 4–5, 8, 10; Okamura, 1908, p. 217, pl. 43; Yamada, 1934, p. 59, fig. 26.

The thallus is simple, clavate, erect, 4–8 cm. high, with the central axis sometimes naked for a short distance at the base of the plant. The stemlike "naked" part may be as long as 2.5 cm., but it bears

scars of branches which have dropped off, the scars being of two sizes, the smaller ones corresponding to whorls of sterile branches and the larger to whorls of fertile branches. The whorls of 3–4 times polychotomous sterile branches are always produced a little above the middle of the distance between the fertile whorls; they number 8–16 per whorl, and are persistent only in the upper part of the plant. The fertile branches number 12–16 (20) per whorl, are 2.0–2.3 mm. long, usually imbricate, and rarely widely spreading. In each of the fertile branches 16–30 aplanospores 150–200 μ broad are produced. The spore membrane is radially striated, 17–30 μ thick, and heavily calcified. The spores remain entirely free from one another.

Distribution. — Liu-kiu Islands, Philippines.

Collections. — *Bartlett 14039, 14040, 14041*, Subic Bay, Zambales Province, Luzon, May. *Albatross Expedition 13*, Subic Bay, Zambales Province, Luzon, Jan. *Shaw 497*, Lamao, Bataan Province, Luzon, May. *Albatross Expedition 12*, Cauanhala Bay, Ragay Gulf, Albay, Luzon, March. *Robinson 6709*, Bulalacao, Mindoro, March. *Albatross Expedition 11*, Mogas Point, Panay, Feb. *McGregor 82*, Bohol Island.

This very interesting material of *Halicoryne Wrightii* Harvey is mostly fruiting. It is interesting to note that the fertile branches are not extended at right angles to the main axis, or reflexed, as has been so often reported, but that they are imbricate, even in the older parts of the plants. Okamura (1908, p. 217) has already mentioned that the fertile branches of specimens of *H. Wrightii* from the Liu-kiu Islands are imbricate.

The other species of this genus, *Halicoryne spicata* (Kützing) Solms-Laubach, was reported from the Philippines by Dickie (1876, p. 243), but his determination appears to have been incorrect, for Solms-Laubach (1895, p. 31), having studied the same material, cites it in his "Monograph of the Acetabularieae" under *H. Wrightii*, with the notation that it is "young and sterile." *H. spicata* has been reported only from Australia, New Caledonia, and three localities at Flores Island, but it would not be unreasonable to expect it in the Philippine flora. It can be differentiated from *H. Wrightii* in that the fertile branches of *H. spicata* reach a length of only 1.3 mm. and have fewer spores than do those of *H. Wrightii*. The spores in *H. spicata* form a mass in the sporangium because their calcified membranes are coherent.

ACETABULARIA LAMOUROUX, 1812

These plants consist of an erect stalk that bears at its upper end a single disclike cap (rarely from 2 to several successive caps), and below the cap, in the upper part of the stalk, from 1 to several whorls of branched deciduous hairs. The cap is composed of many radial segments or rays, which are either free or laterally coherent and which, when mature, contain the aplanospores. On the upper and lower sides of the cap, near the stalk attachment, are 2 cushion-like rings, the upper known as the corona superior, and the lower (absent in some species) as the corona inferior, each being made up of radial segments corresponding in number and position to the rays of the disc. The segments of the corona superior bear a number of deciduous branched hairs or 1-celled hair prominences. The deciduous hairs are represented by a scar when they have fallen off.

A. Side walls of sporangial rays with vertical notched processes that give them a striated appearance; caps 15–22 mm. broad .. 1. *A. major*, p. 29
A. Side walls of sporangial rays smooth, without notch ribs; caps under 10 mm. in width
  B. Sporangial rays with apiculate margin; hair prominences or scars 3–4 on each segment of the corona superior .... 2. *A. dentata*, p. 30
  B. Sporangial rays blunt, with no apiculum; hair prominences or scars 5–7 on each segment of the corona superior
  3. *A. philippinensis*, p. 31

1. *Acetabularia major* Martens

Martens, 1866, p. 25, pl. 4, fig. 3; Solms-Laubach, 1895, p. 22; Yamada, 1925, p. 89; Howe, 1932, p. 169.

The plants are gregarious and reach a height of 4–6 cm. The stalk is heavily calcified, cylindrical, and does not swell in the region of hair-scar whorls; it bears at its summit a single, flat, slightly calcified cap 1.3–2.2 cm. broad and composed of 70–74 sporangial rays held together because of the deposition of lime. The rays separate rather easily after decalcification and have (especially on the inner half) vertical notched processes on their side walls. The apices of the rays are blunt or, rarely, somewhat emarginate (see Fig. 2a). The corona superior is 200–225 μ broad, with the segments rather narrow and not united; each segment has 7–9 hair prominences or scars in a uniseriate row (see Fig. 2b). The corona inferior is 184–210 μ broad, with segments rounded or, rarely,

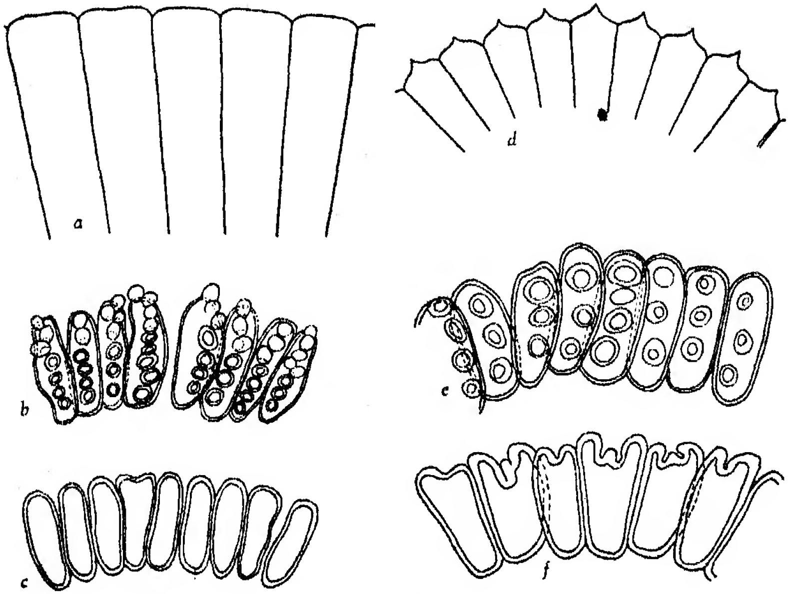

FIG. 2. *Acetabularia spp.: a–c, A. major* Martens; *a*, part of the outer portion of the cap after decalcification, showing the apices of the disc rays, × 16; *b*, a few segments of the corona superior, showing the hair scars and hair prominences, × 68; *c*, a few segments of the corona inferior, × 68. *d–f, A. dentata* Solms-Laubach; *d*, part of the outer portion of the cap after decalcification, showing the apiculate apices of the disc rays, × 22; *e*, a few segments of the corona superior, showing the hair scars, × 148; *f*, a few segments of the corona inferior, × 148

emarginate (see Fig. 2c). The aplanospores are oval, 78–88 μ long and 64–75 μ wide, completely filling the rays.

Distribution. — Thailand, Timor, New Guinea, Philippines.

Collections. — *Bartlett 14042*, Subic Bay, Subic, Zambales Province, Luzon, May; *14144*, Santa Cruz, Zambales Province, Luzon, May. *Albatross Expedition 62.*

2. *Acetabularia dentata* Solms-Laubach

Solms-Laubach, 1895, p. 23, pl. 1, fig. 11; Yamada, 1934, p. 54, fig. 21.

The plants are gregarious and small, reaching a height of only 1–2 cm. The stalk is rather heavily calcified and cylindrical, with or without a single whorl of hair scars just below the single, some-

what saucer-shaped, rather heavily calcified cap. The cap is 1–4 mm. broad and is made up of 28–38 sporangial rays that are not coherent laterally but are held together by the deposition of lime. The rays are apiculate, not often rounded, but usually elevated into a pyramid-like shape at their apical ends (see Fig. 2d). The corona superior is 110–125 μ broad, composed of crowded but laterally free ovate segments, which bear 3–4 hair prominences or scars in a uniseriate row (see Fig. 2e). The corona inferior is 95–120 μ broad, and is composed of rather crowded segments that are distinctly bilobed or, rarely, trilobed at their outer ends (see Fig. 2f). The material is sterile.

Distribution. — New Caledonia, New Guinea, Celebes, Liu-kiu Islands.

Collection. — *Bartlett 14988,* Dalupiri Island, Babuyan Group, Oct.–Nov.

The material agrees well with Solms-Laubach's analysis of the species, differing only in the matter of lobing of the outer end of the segments of the corona inferior. In the collection at hand the ends of the segments are occasionally trilobed, instead of regularly bilobed, as in the original description. Some of the specimens, however, show only bilobed ends on rays of the corona inferior, and those which have ends that are trilobed are never uniformly that way, the trilobed ends always being mixed with bilobed ones.

3. **Acetabularia philippinensis,** sp. nov.

Plantae gregariae, 2–4.5 cm. altae. Frons e stipite valde incrustato et filiformi et leviter incrustato disco composita. Discus solitarius, diametro 3.5–6.0 mm., fere planus, ex 50–67 fertilibus radiis compositus, eisdem elongate clavatis, lateraliter ex basi usque ad apicem liberis, apice rotundatis vel subtruncatis, haud apiculatis; segmentis coronae superioris 140–184 μ longis, inter se liberis, ovatis, pilis 5–7 uniseriatis instructis; segmentis coronae inferioris 155–170 μ longis, ovatis, inter se liberis, externe raro rotundis, saepe emarginatis vel profunde bilobatis.

Specimen typicum: *E. D. Merrill 9123,* ex Taytay, Palawan, Insulis Philippinis, mense Aprili, 1913; in Herbario Horti Botanici, N. Y., conservatum.

The plants are gregarious, 2–4.5 cm. in height. The stalk is heavily calcified, narrow and cylindrical except for slight spindle-

shaped swellings at the 2–6 whorls of hair scars situated in the upper half of the stalk below the single cap which is borne at the summit. The cap is slightly calcified, 3.5–6.0 mm. broad, and flat or nearly so. The sporangial rays, numbering about 50–67, are held together only because of the deposition of lime, and fall apart upon decalcification; they have rounded or, rarely, truncate apices (see Fig. 3a). The

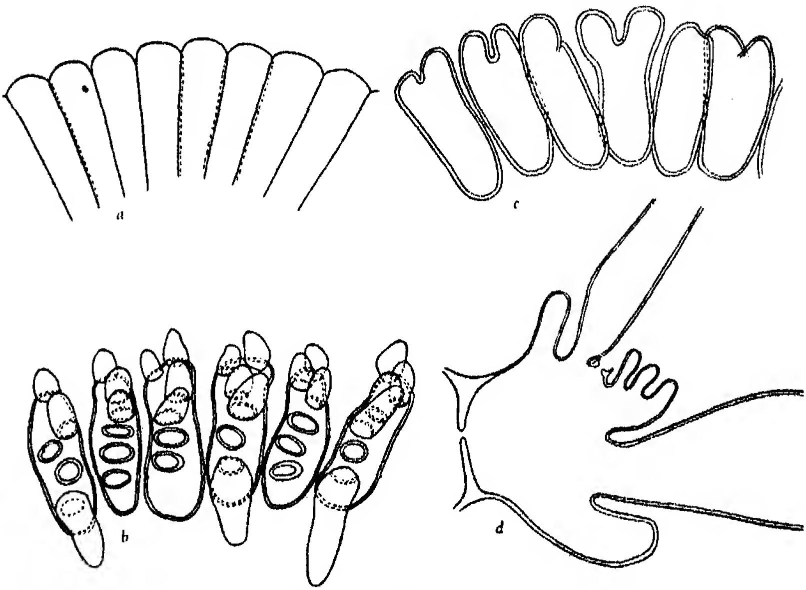

FIG. 3. ***Acetabularia philippinensis***, sp. nov.: *a*, part of the outer portion of the cap after decalcification, showing the rounded or subtruncate apices of the disc rays, × 18; *b*, a few segments of the corona superior, showing the hair scars and hair prominences, × 123; *c*, a few segments of the corona inferior, showing the emarginate to deeply bilobed outer ends, × 123; *d*, a radial-longitudinal section of part of the disc, showing the corona superior (with one hair scar, the base of a hair, and several hair prominences), the proximal end of a disc ray, and, at the bottom, the corona inferior, × 123

corona superior is about 140–184 μ broad, and is composed of longish ovate uncrowded segments bearing 5–7 hair prominences or scars in a uniseriate row (see Fig. 3b, d). The corona inferior is 155–170 μ wide and composed of more or less crowded ovate or slightly wedge-shaped segments, which, at their external ends, are simple, emarginate, or deeply bilobed, often with the lobes asymmetrical in size (see Fig. 3c–d). The plants are sterile.

Collection. — *Merrill 9123* (TYPE), Taytay, Palawan, April, 1913, in the Herbarium of the New York Botanical Garden.

This new species of Acetabularia belongs to the Acetabuloides section of the genus, probably being nearest to *Acetabularia ryukyuensis* Okamura and Yamada (Okamura, 1932). The two species are about the same height and have about the same number of noncoherent rays with truncate or slightly rounded external margins. The new species differs from *A. ryukyuensis* in the cap, which is less broad, as well as in the character and size of the coronae. The segments of the corona superior in *A. ryukyuensis* are oblong, about 250 μ in length, "with 5–6 (mostly 5) hair scars in one row," whereas in *A. philippinensis* the segments are longish-ovate, 140–184 μ long, and bear 5–7 (usually 6) crowded hair prominences or scars in a uniseriate row. In *A. ryukyuensis* the segments of the corona inferior are much shorter than those of the corona superior, and they are oblong, with a rounded external end. They thus contrast with the segments of the corona inferior of *A. philippinensis*, which are approximately of the same length as those of the corona superior and oblong to wedge-shaped, with the outer ends simple, emarginate, or, more often, deeply bilobed.

From other related acetabularias that have no apiculum or vertical notches on the sporangial rays *Acetabularia philippinensis* differs even more decidedly. The numerous sporangial rays with rounded or truncate external margins, the large number of hair protuberances or scars on the segments of the corona superior, and the deep lobing of many of the segments of the corona inferior set it apart from *A. Calyculus* Quoy & Gaimard and the rather questionable species *A. Suhrii* Solms-Laubach, both of which have fewer rays per disc, those rays being emarginate at their apices, with only 2–4 hair prominences or scars on each segment of the corona superior. It is likewise sharply set off from *A. Farlowii* Solms-Laubach, which is not known from Pacific waters. The latter species has only about 30 sporangial rays to a disc, these rays being free, not held together by calcification. In addition, it has but 2 hair scars per segment of the corona superior.

Acetabularia Calyculus Quoy & Gaimard has been listed from the Philippines by Dickie (1877, p. 489), although it does not appear in the collections at hand. The writer has had no opportunity to view the material reported by Dickie, but has no reason to doubt the

correctness of the determination. It may be recognized by its small size, its deeply emarginate sporangial rays, of which there are 22–30 per disc, held together only because of the deposition of lime, and by the oblong to oblong-triangular segments of the coronae, those of the corona superior bearing only 2–3 hair scars.

The genus Acetabularia appears to be very inadequately represented in the Philippine collections, for in addition to the four species discussed above there are at least eight that can be expected in this area. Several of these are extremely small. Forms like *Acetabularia Moebii* Solms or *A. pusilla* (Howe) Collins, which are only 2–4 mm. high, may be easily overlooked, especially by someone whose acquaintance with algae is limited and who does not suspect the presence of such minute forms. A search for these small acetabularias and a more thorough collecting of the larger types ought to reveal a number of species not at present known from the Philippines, and, possibly, several new forms.

The writer wishes to express his thanks to Dr. Wm. Randolph Taylor, professor of botany, University of Michigan, under whose direction the present studies have been carried out.

University of Michigan

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ADDITIONS TO THE FLORA OF MICHIGAN. IV

CLARENCE R. HANES

COLLECTIONS made mainly in 1940 and 1941 by Mrs. Florence N. Hanes and the writer in Kalamazoo County, Michigan, are listed in the present paper. Specimens of most of these have been deposited in the herbaria of the Bailey Hortorium, the University of Oklahoma, and the National Arboretum, at which institutions their identification has been confirmed. At the end of the list of species three corrections are made of plants given in previous papers with incorrect determinations.

An asterisk is used to indicate those species which are, so far as is known, new to Michigan.

List of Species

Sparganium minimum Fries. — Small pond southwest of Pretty Lake in Section 20, Texas Township, September 22, 1941, no. 7241.

Apparently this station extends the range southward in Michigan. The pond is usually full of water, but in September, when specimens were collected, it was almost dry. Many mature seeds and remnants of plants were seen.

Potamogeton Robbinsii Oakes. — Shallow water near the east shore of Austin Lake, August 5, 1941, no. 13641; August 14, 1941, no. 13841.

This pondweed must be erratic in its habits of growth since the summer of 1941 was the first season we saw it here, although it has been our custom for the past six years to visit this lake several times during the summer months, when the westerly winds bring the loosened plants ashore.

Panicum Bicknellii Nash. — Wooded roadside in Section 36, Climax Township, June 20, 1938, no. 778; November 7, 1938, no. 1398.

Both Mrs. Agnes Chase and Mr. J. R. Swallen have referred

our specimens to *P. Bicknellii,* although they are not quite typical.

ERIOPHORUM TENELLUM Nutt. — In Le Fevre Bog, Section 8, Climax Township, June 18, 1941, no. 13441.

It is easy to classify this species wrongly, for it is very similar to *E. gracile*, from which it differs in the color of the scales and the much greater length of the leaves. We find no records for the Southern Peninsula of Michigan.

SCIRPUS SYLVATICUS L. — Border of swamp in Section 6, Oshtemo Township, July 27, 1940, no. 440, and on the border of Little Portage Creek in Section 31, Wakeshma Township, August 12, 1941, no. 16741.

This is an Atlantic Coastal Plain species rarely found inland. I am considering this one of the two recent reports for the state, although it is listed by Beal [1] as from Keweenaw County. This report was, no doubt, based upon a collection of *S. rubrotinctus* Fern., which is plentiful there. Since Kalamazoo County is in the section of the state where there are many Atlantic Coastal Plain species we may reasonably expect to find the plant in southwestern Michigan, but not in the Upper Peninsula. Hebert [2] has a report for Berrien County, which is also in southwestern Michigan.

Fred W. Rapp of Vicksburg made a collection of this plant in August 23, 1941, in Section 10, Brady Township.

*JUNCUS BIFLORUS Ell. f. ADINUS Fern. & Grisc. — Sandy shore on the east side of Austin Lake, August 5, 1941, no. 6541.

Deam [3] gives only one location for this form — in Indiana. Our specimen was checked by F. J. Hermann.

*ARABIS HIRSUTA (L.) Scop. var. ADPRESSIPILIS (Hopkins) Rollins (*A. pycnocarpa* Hopkins var. *adpressipilis* Hopkins). — East of Galesburg, near the Kalamazoo River, June 6, 1940, no. 110.

The range map of Milton Hopkins [4] does not give this variety from Michigan.

*RUBUS MEDIOCRIS Bailey. — Swamp border in Section 28, Portage

[1] Beal, W. J., "Michigan Flora," *Annual Rep. Mich. Acad. Sci.*, 5: 52. 1904.

[2] Hebert, P. E., "Ferns and Flowering Plants of Berrien County, Michigan," *Am. Mid. Nat.*, 15: 327. 1934.

[3] Deam, C. C., *Flora of Indiana* (Indianapolis, 1940), p. 296.

[4] Hopkins, Milton, "Arabis in Eastern and Central North America," *Rhodora*, 39: 117. 1937.

Township, August 5, 1941, no. 3041, and also in Section 10 of this same township, August 21, 1941, no. 3441.

This is a new species, described and published in 1941 by L. H. Bailey.[5] The two stations given above are the only ones from which it has been reported to the present time. The type specimen, no. 3041, is in the Bailey Herbarium, and the isotype is in the Hanes Herbarium.

*Oxalis europaea Jordan var. Bushii Small, f. vestita Wieg. — Wood border in Section 3, Cooper Township, August 27, 1941, no. 14741.

Of the several forms of this species variety *Bushii* seems to have good enough characters to sanction its retention.

*Croton monanthogynus Michx. — Open woodland near the south shore of Wyman Lake, Oshtemo Township, July 23, 1941, no. 7041.

It is difficult to understand how this plant was brought to the place where we found it. It surely is not native to our state. Deam speaks of its weedy nature. Though not yet abundant it has become scattered over a small area.

*Verbascum phlomoides L. — Roadside one mile west of Schoolcraft, near the McCreary farm, August 18, 1941, no. 15741.

It is still rare in our county, since only one plant has been found.

*Coreopsis tripteris L. var. Deamii Standl. — Wood border in Section 8, Charleston Township, August 21, 1941, no. 15941.

This variety has also been found on the west side of the county near Wyman Lake. It often grows with the species, but is readily distinguished from it even at a distance by its darker green color.

Schoolcraft, Michigan

[5] *Gentes Herbarum*, 5: 191–192. 1941.

LIST OF CORRECTIONS FOR PREVIOUS PAPERS

STELLARIA CRASSIFOLIA Ehrh. — This species was reported in 1938 as *S. borealis* Bigel.[6] Since the petals are usually present and are longer than the sepals it should be referred to *S. crassifolia*.

ERYSIMUM PARVIFLORUM Nutt. — Wrongly reported in 1938 as *E. asperum* DC.[7]

*COREOPSIS GRANDIFLORA Hogg. — Incorrectly reported in 1937 as *Thelesperma trifidum* (Poir) Britt.[8] We know of no previous records for this species from Michigan.

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[6] Hanes, Clarence R., "Plants New or Rare in Michigan Records," *Pap. Mich. Acad. Sci., Arts, and Letters*, 24, Part I (1938) : 6. 1939.

[7] *Ibid.*, pp. 6–7.

[8] Hanes, Clarence R., "Additions to the Flora of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 23 (1937) : 139. 1938.

POLLEN ANALYSIS OF A SWEDISH BOG NEAR LAKE STOR-UMAN

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Cooley High School, Detroit
and
ELIZABETH HALFERT
Northern High School, Detroit

POLLEN statistical studies are more complicated in America than in northern Europe because of the much larger woody flora which must be taken into consideration. The European results seem to an American so definite and conclusive that it is natural to wonder whether a study of a Scandinavian locality, particularly if the data are in accordance with those currently obtained by Scandinavian workers, might not give one a feeling of confidence in his own methods and conclusions.

With the greatly appreciated advice of Dr. Gunnar Erdtman a bog was selected for study in the summer of 1938. It is near Lake Stor-Uman, in the southern part of Swedish Lapland, approximately twenty miles south of the Arctic Circle (Fig. 1). The location was sufficiently different from others already studied by Swedish scientists for the results to be used as a small contribution to the body of data on pollen analysis. At the same time, if the findings should be clearly in line with those already published, the study would have a psychological value as well in showing that our procedures in America are comparable and our interpretations valid.

The mountain ranges of Sweden extend from north to south. On the eastern side of the range are many lake basins that resulted from glaciation. Of these, Lake Stor-Uman, with an area of sixty-five square miles, provided the focus for study. To the south of the lake lies Rönnliden State Forest, within which the bog is situated at about 65 N. latitude and 17 E. longitude. The bog itself is in a slight depression below the Baktisjaur hut, at the edge of a miniature

lake known as Lake Fetögat. The region is somewhat higher than Lake Stor-Uman, rising four hundred and twenty-five meters above the sea.

The edge of the bog consisted of sphagnum and herbaceous plants, and a large percentage of ericaceous plants, such as *Vaccinium uliginosum* L., *V. Myrtillus* L., *V. Oxycoccus* L., *Calluna vulgaris* (L.)

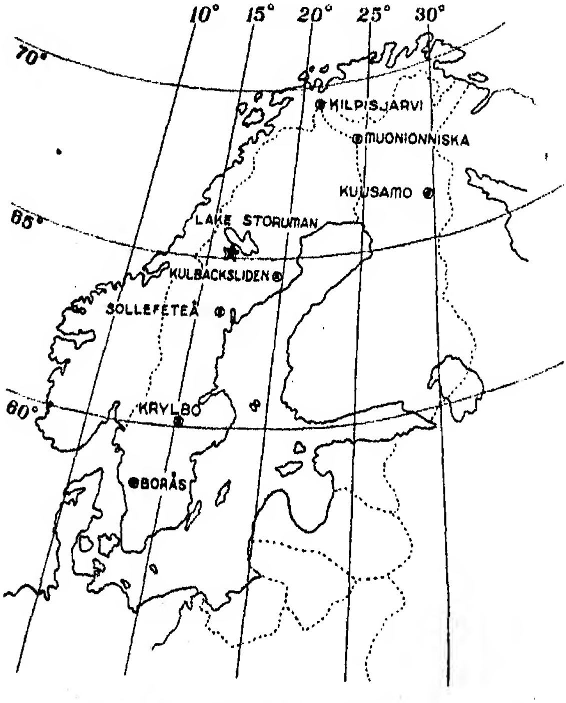

FIG. 1. Location of the bog near Lake Stor-Uman and of others previously investigated by Swedish scientists

Hull., *Eriophorum alpinum* L., *Carex pauciflora* Lightf., *Rubus Chamaemorus* L., and *Scheuchzeria palustris* L. Growing away from the edge were *Picea excelsa* var. *obovata*, *Pinus silvestris* var. *lapponica*, *Betula nana* Willd., and *Salix glauca* L., with the mostly herbaceous cover including *Drosera rotundifolia* L., *D. longifolia* L., *Pinguicula vulgaris* L., *Vaccinium Vitis-Idaea* L., *Parnassia palustris* L., *Menyanthes trifoliata* L., and *Empetrum nigrum* L.

The texture and composition of the peat indicated that the deposit had been built from the ground up, with a constantly rising water table. In other words, at the point where the samples were taken, there had not been an original open water surface on which subaërial peat had formed. The rise of the water table over a whole area owing to bog growth throughout the region would cause the flooding of some areas that were not originally either boggy or open water. Such flooded areas in which peat growth did not keep up with the general rise of the water table would serve to stabilize the gradually rising water table of the bog, since drainage (seepage) could take place in either direction. Such conditions appear to exist at the locality chosen for our study, since there is near it a pond with a

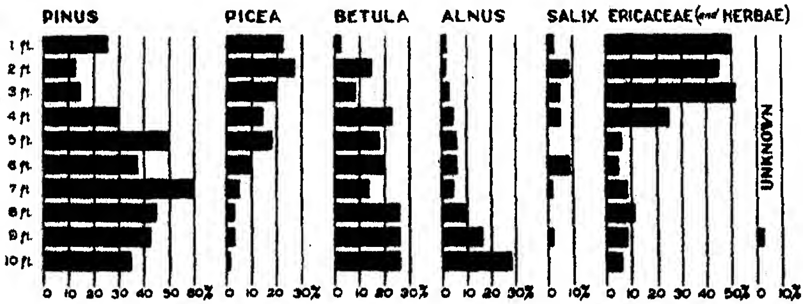

FIG. 2. Pollen profile of the bog near Lake Stor-Uman

drowned peat bottom. This pond had no floating mat, for the footing was solid to the water's edge.

The samples were taken with a Davis peat borer or sampler, beginning at the one-foot level and continuing until glacial clay was reached at the eleven- and twelve-foot levels.

Four slides, prepared according to the method suggested by Dr. Erdtman (1), were made from each foot of material, the general process being that of maceration by alternating mild oxidation and acid hydrolysis. One hundred and fifty pollen grains were counted for each of the ten feet. The samples from the eleventh and twelfth feet consisted of barren glacial clay.

Counting the top sample as the first and continuing downward, we obtained the following results (Fig. 2): Pine was found in increasing amount from the tenth upward to the eighth sample, where it reached its maximum, and from there decreased up to the first,

where there seemed to be a slight increase. Spruce was represented in the tenth layer by only a single grain and showed an increase to its maximum in the second layer, with a very slight decrease at the top. The count for Betula showed a steady drop from the tenth to the first layer. Alnus, abundant at the tenth layer, diminished until only a single grain was found in each of the samples from the first and second layers. There is now no Alnus in the living flora. The ground-cover plants represented in the peat were almost entirely Ericaceae, and their abundance increased decidedly toward the surface, especially in the first three layers.

We find that the results obtained from the study of the Stor-Uman bog conform, in general, with those of other bogs in northern Sweden, as given by Godwin (2) and Von Post (3). This bog lies between Sollefteå and Kulbacksliden, where other bogs have been examined and where similar pollen spectra have been obtained for publication (Godwin, 2, p. 334). In each of these Pinus indicates an increase at the middle and a decline toward the top, with a slightly larger number near the surface. In both, spruce, which is represented by a few grains at the bottom, shows a decided increase at the top.

The Alnus profiles of the bogs are all similar, having a decided decrease from the bottom layers to a complete absence or only an occasional grain at the top. In the upper layers of the Stor-Uman bog the Betula profile does not conform with that for the other two bogs, since in both there is an increase near the surface, whereas in the Stor-Uman bog there is a decrease.

The results of our analysis of a Swedish bog are therefore in agreement with those obtained by Swedish workers. We had wondered what the result of following a definite and accepted tradition in the technique and interpretation of pollen analysis in Europe might be, and, in particular, whether the European peats, examined in the light of American experience, would really prove to be so much simpler in composition than those in America. We found that American peats are actually much more complex, and that the conclusions of European scientists are not based upon oversimplification. Although this was what had been expected, it has, nevertheless, given us greater confidence in the application of the Swedish techniques to our more complex materials. It is likewise of some little value as an addition to the records of Swedish bogs, many of which have been investigated by Erdtman and others.

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FOREST ASSOCIATIONS OF OTTAWA COUNTY, MICHIGAN, AT THE TIME OF THE ORIGINAL SURVEY

LESLIE A. KENOYER

WHEN the land of southwestern Michigan was surveyed for settlement, in the 1820's and 1830's, the surveyor recorded by name two reference trees selected at each section corner and at the mid-point of each section boundary. Copies of field books of the survey are on file at each county seat. After indicating at the proper points on a county map the species of reference trees recorded by the surveyor one can outline with considerable confidence the forest distribution at that time. Woodlots now standing are so fragmentary that, though in the main they agree with the surveyor's record, they present a less accurate picture of the former distribution of associations.

In three papers previously presented before the Academy (1, 2, 3) the writer mapped and discussed the distribution, indicated in the survey, for nine of the counties of southwestern Michigan. In May, 1941, he examined the field books of Ottawa County and mapped the associations. This county lies just to the north of Allegan County, one of the group previously studied, and borders Lake Michigan on the west. It was surveyed in the years 1831 to 1834.

In the earlier studies the associations were designated as beech-maple (often including hemlock), oak-hickory, oak-pine, prairie with scattering bur oak, lake, and swamp. Hemlocks were entirely and pines mainly restricted to the counties bordering Lake Michigan, where, also, beech and maple were most extensive. Prairies were limited to the two southern tiers of counties. Oak-hickory and prairie associations are not found in Ottawa County. There are two areas that seem to be prevailingly pine and oak, and several relatively small swamp areas. It most closely resembles Allegan County, but exceeds that county in the proportion of beech, maple, and hemlock. A comparison of the two is given on page 49, the figures representing percentages.

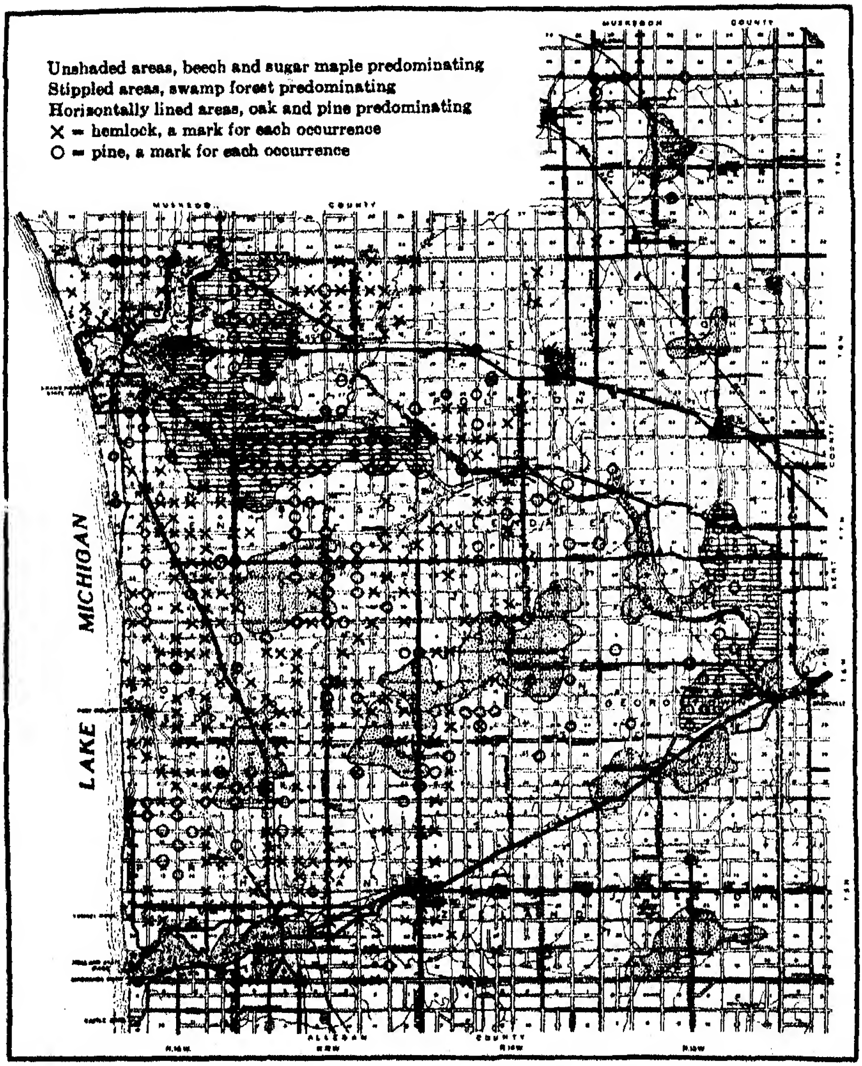

Fig. 1. Forest map of Ottawa County, Michigan

FOREST ASSOCIATIONS OF ALLEGAN AND OTTAWA COUNTIES

Associations	*Allegan*	*Ottawa*
Beech-maple (with hemlock, especially in the half nearest the lake).......	69	85
Oak-pine	16	7
Oak-hickory	8	0
Lake and swamp	7	8

Of the trees marked by the surveyor as bearing trees, usually two at each section corner and two at the middle of each section boundary, the most frequent species are, in percentages of the whole number:

Beech	33.7
Hemlock	13.5
Sugar maple	12.5
Pine (species not designated)	8.6
Black and white ash	7.3
All oaks	5.1
Soft maples	5.0

It is obvious from Figure 1 that hemlock and, to a somewhat lesser extent, pine (species not indicated) were more abundant in the portion of the county nearer Lake Michigan. A strip twelve miles broad next to the lake includes about half of the area of the county, about five sixths of the hemlocks recorded as reference trees, and about three fourths of the pines.

Noteworthy features of Ottawa County, as compared with the more southerly area, Kalamazoo and the adjoining counties, are the absence of grassland areas, the scarcity of oaks, and the extreme scarcity of hickories. Another evident fact is the less definite indication of boundaries between the associations. There is more of a tendency for certain species to be scattered over the various environments in the area.

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REGENERATION IN *RADICULA AQUATICA* *

CARL D. LA RUE

MANY papers have been published on regeneration of plant parts. Among them are those on leaves, by Kupfer (4), La Rue (5), Loeb (10), and Stingl (13); on stems, by Goebel (2), Kupfer (4), Loeb (10), and Vochting (14); on roots, by Beals (1), Graham and Stewart (3), Kupfer (4), Naylor (12), and Vochting (4); and even on flowers and fruits, by Goebel (2), Kupfer (4), and La Rue (9). So large, indeed, is the number of such papers and so many are the species treated in them that the addition of another title to the list would not be worth recording did it not concern a species of unusual capacity both for vegetative reproduction and for true regeneration. The lake cress, *Radicula aquatica* (Eat.) Robinson, is a species of this character.

Brief examination of a thriving colony of *Radicula aquatica* in midsummer is all that is needed to convince one of an extremely high rate of propagation of this species by vegetative means. Further acquaintance shows that it has remarkable ability to regenerate new buds and roots from all its parts, which is rather surprising in a plant with a highly specialized method of vegetative reproduction. It is a plant so highly propagative that few others can equal it in this respect, and it deserves more than the brief notice it has already received (6, 7, 8).

HABIT AND HABITAT

Radicula aquatica is an aquatic herbaceous perennial belonging to the Cruciferae; it is closely related to the water cress, *Radicula Nasturtium-aquaticum*, and to the horse radish, *Radicula Armoracia*.

The species is widespread throughout the northeastern United States, and once established in a stream it becomes extremely abundant, but it is known to the author from only a few localities. It produces a small number of seeds, and its method of reproduction is

* Papers from the Department of Botany of the University of Michigan, No. 808, reporting work done at the University of Michigan Biological Station.

better suited for local spread than for long transportation. Whether this or a special habitat or a combination of the two accounts for its rather infrequent occurrence is not yet known.

Streams four to six feet deep with mucky bottoms are favored by this species. Young plants grow in shallow water and even on wet muck above the water, but do not thrive there. The stem bases of mature plants remain alive in the muck over the winter, after the upper parts have died and rotted. In the spring the side buds grow out from the old stems and produce rosettes of leaves, which are much branched and very finely divided.

Later in the season the stems grow upward rapidly through the water. As they ascend the leaves formed in succession are less and less divided, and those produced near the surface of the water are only slightly lobed. The leaves that are formed above the water surface are entire or barely notched. This variation of leaf form in relation to differences in depth of immersion in water is even more extreme than that described by McCallum (11) for *Proserpinaca palustris.*

The rosette leaves are long-petioled and have numerous long filamentous tips. Those formed on the stem immediately above the rosette have short petioles and show a well-developed midrib, from which great numbers of branched segments arise. Above these leaves come a series which have numbers of toothlike lobes that are unbranched. This lobing becomes less and less pronounced as the stem nears the surface of the water until, as has been said, it emerges from the water and bears entire leaves on its upper portion.

As seen from above, the basal rosettes in the water are tufted and very handsome, but the emerged stems are weedy and unkempt in appearance from the loss of the aërial leaves, which fall off at the slightest touch.

Microscopic sections show abscission layers at the bases of the leaves. On the emerged leaves these are well developed, and nearly all the leaves except the very young ones are soon broken off. Downward from the surface of the water one finds the abscission layer less developed in each successive leaf. The rosette leaves, which are not easily detached, ordinarily remain on the plant until winter, or even until early in the following spring. If one pulls a plant up from the muck he usually finds that only the youngest leaves at the tip of the stem and the rosette leaves at its base remain attached.

In the vicinity of Cheboygan, Michigan, where the following studies were made, some of the plants begin flowering in early August, but not many fruits form, and it appears that few of these can ripen before the early frosts kill them. Ripe seeds have never been found in that locality, and it seems likely that, in latitudes so far north at least, the species depends mainly on vegetative propagation for its distribution.

VEGETATIVE REPRODUCTION

It has been found that buds are produced on the stems in the axils of the leaves and also beyond the abscission layer in the petioles themselves. Consequently, when the leaves break off from the stem they leave one or more buds at each node of the stem and bear two or three buds in the base of each petiole. Since the plants grow in water the leaves fall on its surface, and the buds begin growth. Within a week several roots have appeared on each petiole, and a shoot has started from one of the buds. As the new plant grows the leaf from which it has sprung begins to die. Finely divided leaves appear to perish earlier than entire leaves, but both types persist for some time after the new plants have been formed.

Vast numbers of new plants are produced in streams where *Radicula aquatica* is abundant, and the surface of the water is covered with tons of leaves and young plants. Some of the young plants drift out to the stream banks and attach themselves to the mucky soil there; more of them drift down the streams and out into the lakes or larger streams, where they are lost; still others sink to the bottom of the water as the leaves which formed them decay and as the weather grows colder and cloudier. Thus these little plants serve as hibernacula, and if they do not root on the bottom during the winter they float up to the surface with the advent of more intense sunlight in spring, and continue their journey.

Roots and shoots do not always develop with equal rapidity on these leaves. Buds usually grow out most rapidly when the leaves float on water, but roots form more rapidly on leaves laid on moist filter paper in closed glass containers. This is clearly shown in Table I.

Vegetative propagation of this plant takes place in nature also when stems are broken off, or bitten off, from their bases. The buds at the nodes then grow out, forming shoots which produce roots at

their bases and mature into new plants. For convenience details of the development of stem buds will be treated under the topic of "Regeneration."

TABLE I

ROOT FORMATION IN WATER AND ON MOIST PAPER

Type of leaf	No. of leaves	Substratum	Number of roots formed		
			In 4 days	In 8 days	In 12 days
Whole leaves	20	In water	8	36	36
	20	On moist filter paper	28	75	75
Leaves with bases of petioles cut off to remove preformed buds	20	In water	..	3	7
	20	On moist filter paper	..	20	33

REGENERATION

Regeneration is now usually distinguished from vegetative reproduction, and the term is applied to the formation of new buds and roots, whereas the production of plants from preformed buds is considered to be merely vegetative multiplication. In the preceding paragraphs the usual means of propagation of the plant has been discussed. In some sections of the treatment of regeneration examples may be given which technically belong under vegetative propagation, but it seems more convenient to group them in such a way as to show the actual behavior of the parts rather than to be meticulous as to the separation into proper categories.

Regeneration in Leaves

When the bases of leaves are cut off — and thus all preformed buds are removed — regeneration of roots and buds takes place. Roots are formed within eight days, as is shown in Tables I and II. Bud regeneration takes longer, but within two weeks most of the petioles will have formed new buds.

The regeneration of roots on disbudded leaves, like root formation on whole leaves, occurs more rapidly on moist paper than in water, as Table I indicates.

The vegetative outgrowth of roots on whole leaves appears to be slightly inhibited by light, but, on the contrary, light is beneficial to regeneration of roots on disbudded leaves. If, however, growth hormones are applied to the leaves in lanolin the effect of light is lost. Table II is representative of a series of experiments on the effect of light and of growth hormones.

TABLE II

THE EFFECTS OF LIGHT AND OF GROWTH HORMONES ON ROOT FORMATION ON LEAVES

Type of leaf	No. of leaves in each set	Number of roots formed in 8 days					
		In light			In dark		
		Un-treated	2 % indole acetic acid	2 % indole butyric acid	Un-treated	2 % indole acetic acid	2 % indole butyric acid
Whole leaves	20	51	65	119	81	71	128
Leaves with bases of petioles cut off to remove pre-formed buds ...	20	15	14	65	2	28	45

Mutilated leaves and parts of leaves regenerate buds readily, but only in light. Since bud formation is slower than root formation, it is to be expected that it would be less successful in the dark than in the light because of the etiolation of the leaves during the period they are kept in darkness. As is shown by trials, the leaves do not keep in good condition in the dark long enough to regenerate buds.

Leaves cut into narrow slices from base to tip, with enough of the lamina left intact at the tip to hold the slices together, will form buds and roots at the base of the petiole and wherever cuts have severed large veins. If the slices are made in a similar manner, but from tip to base, regeneration rarely occurs in whole leaves. The preformed buds in the petiole appear to inhibit bud formation elsewhere. If the petioles are disbudded, buds will form at the base of the petiole and along the cuts where large veins have been severed.

If leaves are cut into slices 2–3 mm. wide in a crosswise direction

and only enough of the lamina is left intact on one side to hold the slices together, many of the slices will form buds and roots on their lower edges. Neither buds nor roots are formed on the upper edges of the slices. If the petioles are disbudded, more of the slices will regenerate and do so more rapidly. The inhibiting effect of the preformed buds is thus shown, even though the path of any inhibiting substance must travel through a narrow channel along the uncut margin of the leaf and sidewise through the slices. Buds and roots on the slices are usually formed on the cut midribs, but sometimes they are on the lower ends of the larger veins.

Midribs of leaves from which the lamina have been removed, whether disbudded or not, behave almost like whole leaves, but show somewhat weaker growth. Crosswise and lengthwise slices of leaves only 2 mm. wide have formed new buds and roots.

The smallest piece of leaf known to regenerate was the tip of one of the filamentous divisions of a submerged leaf. It was only 1 mm. in diameter and 5 mm. long, but it formed a bud on the cut base.

Regeneration in Stems

On stems growing naturally in the water branching does not occur. Late in the season short roots grow out from many of the nodes below the water surface, after the leaves have fallen. The buds at these nodes usually elongate slightly, and then remain completely inhibited, unless the stem tip has been removed.

Pieces of stem containing ten nodes were cut, with stem tips and clusters of terminal leaves intact on them. Kept in damp chambers on moist paper, they promptly formed roots at the lower nodes, but no shoots at all.

Similar stems with stem tips and all leaves removed formed a strong shoot at the terminal node of each, a small shoot at each of the two next lower nodes, and no shoots at any other node. Roots were formed at five or six nodes of the basal end.

Stem pieces with fewer nodes behaved in the same way. Even a half stem with two nodes produced at the upper node a strong shoot which inhibited the growth of a shoot from the lower node.

Pieces of stem with two nodes were split from the top down almost to the base, with the cut running between the buds on these nodes. Shoots grew out from both nodes of these pieces.

Lengthwise slices of stem, halves, quarters, or slices of cortex,

provided they bear buds, act in the same way as whole stems. A thin lengthwise slice of cortex through one node and parts of the adjoining internodes produced a shoot from the bud at the node.

Crosswise slices, only 1 mm. thick, through nodes of stems 1.5 mm. in diameter have produced shoots from nodal buds.

In view of the strong inhibitory effect which terminal shoots exercise over the buds below them on the stem an experiment was set up to test the effect of growth hormones as bud inhibitors. In each set twenty stems were used, all of the same length, of comparable size, and containing approximately the same number of nodes. Counts were made at the end of eight days. The results are shown in Table III.

TABLE III

THE EFFECTS OF GROWTH HORMONES ON ROOT AND SHOOT FORMATION ON STEMS

Treatment	Stems without leaves		Stems with leaves	
	Roots	Shoots	Roots	Shoots
In light	398	37	477	37
In light, with 2 % indole acetic acid in lanolin	633	14	333	21
In light, with 2 % indole butyric acid in lanolin	693	12	678	20
In darkness	520	48	398	43
In darkness, with 2 % indole acetic acid in lanolin	963	16	622	15
In darkness, with 2 % indole butyric acid in lanolin	1280	0	549	0

Table III shows a strong stimulation of root formation by the growth hormones, as Table II indicates for leaves. It is rather interesting that both indole acetic acid and indole butyric acid are able to produce additive effects in a plant already very potent in root formation.

Both hormones are able to inhibit shoot growth, but only indole butyric acid was able to inhibit it completely, and that only in the dark.

In another experiment pieces of stem were cut to uniform length. In one group a single node was included in each stem piece; in the

other the pieces consisted of internodes only. All the segments were kept on moist paper in glass damp chambers. Twenty stem segments were used in each set. The data, which were taken at the end of fourteen days, are presented in Table IV.

TABLE IV

THE EFFECTS OF GROWTH HORMONES ON ROOT AND SHOOT FORMATION ON NODES AND INTERNODES

Treatment	Nodes		Internodes	
	Roots	Shoots	Roots	Shoots
Controls	9	16	0	0
2 % indole acetic acid in lanolin	56	16	11	0
2 % indole butyric acid in lanolin	126	0	57	0

As shown in Table III, only indole butyric acid is able to inhibit buds completely. Indole acetic acid does not appear to inhibit the buds on single nodes. Both of the growth hormones stimulate root growth at the nodes and induce root regeneration on the internodes.

All the preceding results with stems, except the data on internodes in Table IV, may be considered mere vegetative multiplication, since the buds were present at the beginning of the trials. But the stems are capable of true regeneration. Segments of stems from which the nodal buds have been cut out are able to regenerate new buds on the cut surfaces. Also, pieces of stem containing three nodes which have been divested of all cortical tissue and all buds as well will form new buds at the nodes. Pieces of internode, after some delay, will regenerate buds from vascular bundles on the basal end. Table IV shows that such internodes will form roots rather readily if stimulated by growth hormones, but such root formation has been secured without their use by putting pieces of internode in sterile culture on nutrient agar.

Regeneration from Roots

All the roots of *Radicula aquatica* are small and fibrous, and hence are of a type little suited for propagation. Repeated trials with pieces of roots in water and on moist paper in damp chambers showed

no regeneration at all. Finally, a number of pieces of roots were sterilized and cultured on sterile nutrient agar made up according to White's formula (15). The pieces of roots were segments 5 mm. long, cut from roots 1 mm. or less in diameter. No sign of development was observed for a long time, and daily examinations of the cultures gave way to infrequent ones. Because of this the exact time required for regeneration from these root segments is not known, but it is probably not less than sixty days nor more than ninety days.

The segments of roots did not branch, but tiny buds appeared in the middle portion of each of those which grew. Later shoots sprouted out from these buds, and new roots were formed on their bases. The small plants thus produced developed rapidly and formed normal plants.

Regeneration from Fruits

Buds and whole flowers were sterilized and cultured on nutrient agar. Sepals, petals, stamens, and pistils were cultured separately. Since the author had rooted petals of *Epilobium angustifolium* (9), it seemed probable to him that petals of *Radicula aquatica*, which come from a very regenerative species and which are about the same size as those of *Epilobium angustifolium*, could be rooted also. Apparently they could not. Sepals and stamens have never been rooted, and so their failure here was not unexpected. Several of the ovaries produced single roots from their cut basal ends.

Regeneration from Bud Meristems

The author has already reported the growth of bud meristems of Radicula in sterile culture (6). They were dissected from the buds and represented masses of meristematic tissue under 0.5 mm. in length. These meristems produced shoots on which roots were formed, and ultimately normal plants were developed from these small primordia. So far as the author has been able to discover, complete plants have not been grown from such minute masses of terminal meristem from any other species.

DISCUSSION

Considerable discussion of different phases of the reproductive activity of this species has been interlarded with the data and need not be repeated here. There are, in all probability, other plants

which have capacities for vegetative propagation and for regeneration equal to those of *Radicula aquatica,* but as yet none of them have been so completely explored. Little has been added here to our small knowledge of the factors which enable a plant to regenerate. But more progress is being made now on problems of growth and differentiation than has been attained in any previous period. As one of the most propagative and regenerative plants in existence *Radicula aquatica* should be a good subject for use in the study of these problems.

SUMMARY

1. Vegetative propagation of the species from leaves and stems is described.

2. Disbudded leaves produce new plants by bud regeneration. Sections of leaves, of a variety of shapes and sizes, are capable of regeneration.

3. Nodes deprived of buds are able to form new buds, and internodes in culture on nutrient agar are able to form both buds and roots.

4. Polarity is shown in developments from leaves and stems. Shoots on the upper stem strongly inhibit shoot development below them.

5. Indole acetic acid inhibits shoot growth on stems, but indole butyric acid produces a much stronger inhibition of outgrowths from buds.

6. Both indole acetic acid and indole butyric acid stimulate root formation on leaves and stems, but indole butyric acid shows the greater effect.

7. In culture on nutrient agar minute pieces of root are able to form new plants.

8. Meristems less than 0.5 mm. long have produced new plants on nutrient agar.

9. Ovaries dissected from mature flowers and placed on nutrient agar have formed roots on their basal ends.

10. *Radicula aquatica* is unusual in its ability to multiply by vegetative propagation and by regeneration.

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CLADONIA ALPICOLA IN NEW YORK STATE *

JOSIAH L. LOWE

THE Cladonia flora of most of the northeastern United States is well known through the collections of Tuckerman, Farlow, Robbins, Evans, and others. The alpine areas, however, have never been surveyed intensively by lichenists. The noteworthy discovery of a boreal Cladonia, here reported, on the summit of the highest mountain in New York State suggests that these mountain areas

A B C

FIG. 1. A and B. Habit of the plant, × 1. C. Enlargement of the podetium, × 6. The peltate podetial squamules diagnostic for the species are distinct in the right-hand figure

offer a promising field for studies in the distribution of the northern Cladoniae.

Cladonia alpicola (Flot.) Vainio is a lichen that is readily identified, in its typical forms, by the large squamules of the primary thallus and by the peltate squamules on the podetium (Fig. 1). According to the literature (6), this lichen has been collected most frequently in the northern parts of Europe. It has also been noted from

* Paper from the Department of Forest Botany and Pathology, New York State College of Forestry, Syracuse, New York.

widely scattered stations in America: var. *foliosa* (Sommerf.) Vainio from Greenland and Newfoundland, by Wainio (5); and f. *Mougeotii* (Del.) Vainio, f. *minor* Vainio, and f. *Ehrhardtiana* Vainio from Alaska, by Merrill (3). Connecticut records of var. *karelica* Vainio (1) were later retracted, and a report of f. *minor* was qualified by several statements which indicated an uncertain classification of the collection (2). Nearing (4) includes this species in his lichen book, but does not say where it has been collected.

Typical plants of *Cladonia alpicola*, referable to var. *foliosa* f. *Mougeotii*, have been collected by the writer on Mount Marcy at elevations from 1,524 to 1,615 meters (5,000–5,300 feet) above sea level. They are rather uncommon, and reach their best development among moss on soil in moist protected cracks in rocks. The description given below is drawn from specimens found on Mount Marcy.

Squamules of the primary thallus usually persistent, thick or rather thick, of moderate size to large, 3–10 mm. in greatest dimension, simple or with broad lobes, esorediate, KOH —, above light to more commonly dark greenish gray, impressed-areolate or, more rarely, the minute areoles separating and showing the white cortex within, below white except more or less brown at the base close to the substratum; podetia arising from the upper surface of the squamules, ascyphous, branched 1–4 times, usually 1.5–2.5 cm. in length, reaching an extreme length of 3.5 cm., cylindrical, about 1–2 mm. in diameter, the tips of the branches sterile or with small black sterile fruiting bodies; surface of the podetium at first similar to that of the primary squamules, very soon breaking up to form verrucae or, more often, peltate squamules, which may remain for a long time attached at the center, or fall off and expose the white or whitish, fibrous, sulcate chondroid layer beneath, or at times persist and elongate on one side to form squamules up to 1 mm. or more in length; fertile conidangia not found, nor apothecia.

Dr. E. W. Evans kindly examined a specimen and verified the species determination, adding that the plant should be referred to f. *Mougeotii*.

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THE DESMID GENUS MICRASTERIAS AGARDH IN SOUTHEASTERN UNITED STATES

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IT IS the intention of the authors in this and subsequent articles to add to the knowledge of desmid distribution and ecology, with special reference to southeastern United States. In an earlier paper (14) they pointed out that in the states bordering the Gulf of Mexico many of the algal habitats support desmid floras which are as luxuriant as those of the highly glaciated regions of North America. Their recent collections of fresh-water algae from Florida, Mississippi, and Louisiana make possible further comparisons of northern and subtropical desmid floras in this continent.

It is of interest to note that as these studies progress additional species previously reported only from New England or Newfoundland are found also in the subtropical Gulf region. The character of the desmid flora of the sandy soil ("yellow podzol") of the Gulf and the southeastern coastal plains of the Atlantic seaboard raises the old, interesting questions regarding the factors which determine the distribution of these plants. As data accumulate there is increasing evidence that these factors are specific and do not have a broad application to the family, or even to genera. Temperature and light periodicity seem to be important in limiting the distribution of some species, while water chemistry is a significant and determining ecological factor for others. *Micrasterias foliacea* Bail., for example, is found from subarctic to tropical regions, but its occurrence is so specifically related to water chemistry that the species can be used as an index organism for soft and highly acid water.

According to the authors' observations, the acidity of the water in which it grows may be predicted with assurance as lying between pH 5.8 and pH 6.4 (rarely as high as pH 6.8). *M. rotata* (Grev.) Ralfs on the other hand is not confined to an acid habitat, but is more ubiquitous, and not infrequently may appear in the microflora of habitats possessing a pH as high as 7.4. Some of the planktonic species, such as *M. radiata* (Grev.) Ralfs and its varieties, show a similar lack of restriction to acid habitats.

In their studies of desmid distribution the authors have observed that it is unusual for a habitat to have but one or two species of Micrasterias. Either there are a number of species or none, although in any case there may be an abundance of other desmids. This suggests a preference amounting to a generic selectivity on the part of Micrasterias species for a particular combination of chemiophysical factors. In subsequent studies this question will be examined in the hope of determining the limiting factors which are involved in this distribution.

Results of the present survey of the algal flora in the Gulf states support the observations of G. M. Smith, and of others who have found it necessary to take exception to the statements and theories of the Wests in England and Wittrock in Sweden regarding desmid distribution. It was the contention of these phycologists that desmid floras dominate only in water standing over or draining igneous rock. In general, desmid studies in New England support this idea, for here many algal habitats are underlain by ancient rock and the flora is predominantly of the desmid type. Rich desmid floras of a character somewhat similar to that of the rocky parts of New England appear, however, in the sand-plain lakes and bogs of southeastern New England, in the glacial drift of the upper Great Lakes region, and in the sandy soil of the Gulf Coast, none of these habitats being associated with igneous rock. The fact that desmids are abundant in respect to number of both species and individuals in water draining igneous rock as well as in sandy-soil substrates immediately suggests, of course, that there are similarities in the water chemistry of these two types of environments.

It is a well-known fact that desmid floras are best developed in water having a low pH (5.2–6.8). This is undoubtedly a correlation and not a causal relation. We know that desmids are abundant in water which contains a required optimum ratio of K–Na ions to

Ca–Mg. When the K–Na/Ca–Mg ratio is high, the water is of course relatively more alkaline. Calcium-rich lakes are, therefore, unfavorable for desmids, as are also soft-water lakes which are poor in nutrient ions.

The present paper deals with the genus Micrasterias, which includes some of the most beautiful plants in the Desmidiaceae. Cells of a number of species have a volume greater than that of almost any other desmid. Although the cell is usually very flat, having a thickness which may be only one sixth of the maximum dimension, the width is nearly always as great as the length (rarely greater) and the cell is approximately circular in outline.

The genus is unique among the Cosmarieae because of the definiteness with which it is separated from other members of the tribe. There are not, for example, intergrading forms, as there are between Cosmarium and Staurastrum and Euastrum or between Xanthidium and Arthrodesmus. Micrasterias is a highly derived genus in the desmid family, and one which is to be regarded, in so far as present evidence indicates, as terminating a line of evolutionary development.

With some exceptions, the taxonomic list below follows Krieger (8), who has done much to simplify the synonymy of Micrasterias species.

The senior author wishes to acknowledge with gratitude grants in aid from the Horace H. Rackham and Mary A. Rackham Fund and the American Association for the Advancement of Science which facilitated the preparation of an iconograph used in this study. These grants also made possible some of the field work upon which certain portions of this study are based. The authors are indebted to Dr. Hannah Croasdale for her help in preparing Latin diagnoses.

List of Species

Micrasterias americana (Ehr.) Ralfs (f.) (Pl. I, Fig. 5). — Length 138 μ, width 114–120 μ, isthmus 22.5 μ. Florida; Sorrento, Covington, Louisiana.

Micrasterias americana var. Hermanniana Reinsch. — Florida (Wolle, 1892).

Micrasterias arcuata Bail. — Length 70–100 μ, width 65–80 μ, isthmus 14 μ. Swamp near New Smyrna Beach, Florida.

Micrasterias arcuata var. expansa (Bail.) Nordst. (Pl. I, Fig. 11;

Pl. VI, Figs. 2, 4). — Length 70 μ, width 67 μ, isthmus 11 μ. Sphagnum swamp near Pearl River, Louisiana; Florida.

Micrasterias arcuata var. gracilis W. & G. S. West (Pl. I, Fig. 15). — Length 75–85 μ, width 75–90 μ, isthmus 10–11 μ. Alabama (Brown, 1930); pond near Osteen, Florida.

Micrasterias arcuata var. **lata,** var. nov.[1] (Pl. I, Fig. 14; Pl. V, Fig. 2). — A very wide variety with both polar and lateral lobes greatly extended; apex broadly convex, slightly retuse in the median portion, extended into long, gradually tapering, slightly recurved arms which are tipped with a stout spine; lateral lobes disposed horizontally, very wide and stout at the base, tapering gradually to bifurcate tips, which slightly exceed the converging apical lobes; semicell with subparallel margins between the lateral and apical lobes; sinus widely open from broadly rounding angles; length 88–95.5 μ, width 133.2–155.4 μ, isthmus 14.4 μ. Lake Alfred near Winter Haven, Eustis Lake near Eustis, Florida.

This plant of unbalanced proportions suggests some of the varieties of *Micrasterias pinnatifida* (Kuetz.) Ralfs. Our specimens are all much wider than *M. pinnatifida,* and the tapering, slightly recurved arms of the polar lobe are similar to those of *M. arcuata.*

Micrasterias arcuata var. robusta Borge (Pl. VI, Fig. 3). — Length 55 μ, width 48 μ, isthmus 9.5 μ. Sphagnum bog 2 miles west of Pearl River, Louisiana.

Micrasterias conferta var. **glabra,** var. nov.[2] (text fig. 1). — A variety differing from the typical plant in its lack of spines within the dorsal margin of the polar lobe, and in having a mam-

[1] *Micrasterias arcuata* var. **lata,** var. nov. — Varietas latissima, lobis polaribus lateralibusque admodum extensis; apice late convexo, in media parte paululum retuso, in bracchia longa, gradatim attenuata, paululum recurvata, spinaque crassa praefixa, prolongato; lobis lateralibus horizontaliter productis, in basi latissimis crassissimisque, ad cacumina bifurcata, extra lobos apicales convergentes paululum excedentia gradatim attenuatis; semicellula margines subparallelos inter lobos laterales polaresque habente; sinu late aperto et ab angulis late rotundatis egrediente. Long. 88–95.5 μ, lat. 133.2–155.4 μ, lat. isth. 14.4 μ.

[2] *Micrasterias conferta* var. **glabra,** var. nov. — Varietas a typica planta differens inopia spinarum intra marginem dorsalem lobi polaris atque possessione protuberationis mammillatae in basi utriusque anguli lobi polaris; spina parva obtusa in apicibus lobulorum polarium; apicibus lobulorum lateralium autem processibus spinosis non praeditis velut in planta typica. Long. 97 μ, lat. 85 μ, lat. isth. 14.5 μ.

millate protuberance at the base of each angle of the polar lobe; a small blunt spine at the apices of the polar lobules; apices of lateral lobules without spiny processes, as in the typical plant; length 97 μ, width 85 μ, isthmus 14.5 μ. Rare in Devil's Swamp, 2 miles east of Westonia, Mississippi.

The polar lobe of this variety is very similar in shape and depth of incision to that of var. *hamata* Wolle, but its margins are quite smooth.

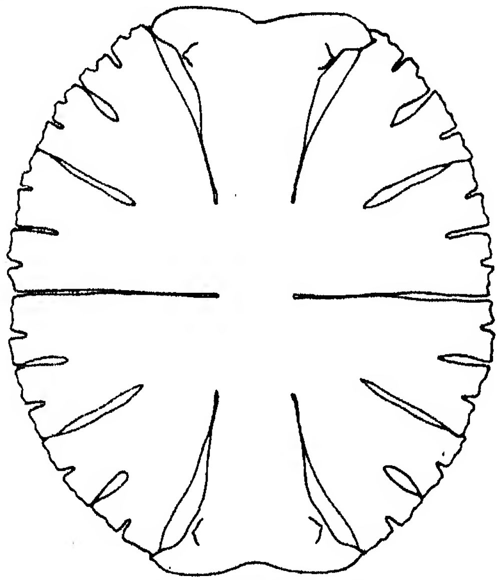

FIG. 1. *Micrasterias conferta* var. *glabra*, var. nov.

MICRASTERIAS CONFERTA var. HAMATA Wolle (Pl. I, Fig. 6). — Length 97 μ, width 82 μ, isthmus 13 μ. Florida; Picayune, Mississippi. Rare in the Gulf states region.

MICRASTERIAS CONFERTA var. HAMATA f. **spinosa**, f. nov.[3] (text fig. 2). — A form differing from the typical variety in having stout spines within the margins of the polar lobe and the inner

[3] *Micrasterias conferta* var. *hamata* f. **spinosa**, f. nov. — Forma a typica planta differens possessione spinarum crassarum intra margines lobi polaris marginesque interiores loborum superiorum lateralium; necnon spinis secundum margines basales semicellularum praedita. Long. 99 μ, lat. 86 μ, lat. isth. 13.5 μ.

margins of the upper lateral lobes; also with spines along the basal margins of the semicells; length 99 μ, width 86 μ, isthmus 13.5 μ. Rare in Devil's Swamp, 2 miles east of Westonia, Mississippi.

MICRASTERIAS CRENATA De Bréb. — Florida (Bailey, 1851).

MICRASTERIAS CRUX-MELITENSIS (Ehr.) Hass. (Pl. V, Fig. 7). — Length 144 μ, width 104 μ, isthmus 18 μ. Everglades, Florida. Coll. Ruth Patrick. New for the region.

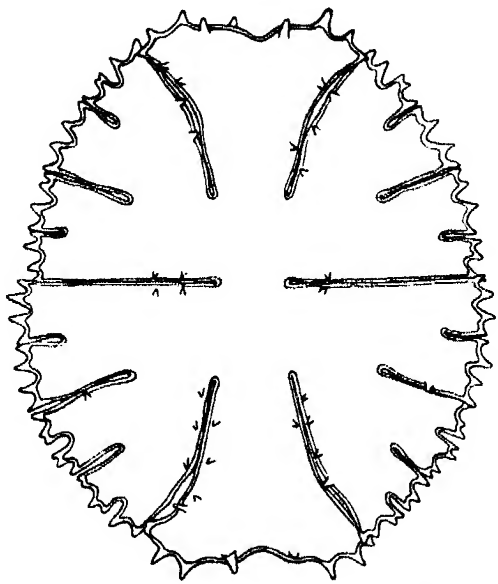

FIG. 2. *Micrasterias conferta* var. *hamata* f. *spinosa*, f. nov.

MICRASTERIAS DECEMDENTATA (Naeg.) Arch. — Florida (Borge, 1909; Wolle, 1892).

MICRASTERIAS DENTICULATA De Bréb. (f.) (Pl. II, Fig. 1). — Length 155 μ, width 130 μ, isthmus 25 μ, width of polar lobe 57 μ. Alabama (Brown, 1930); Florida; Slidell, Louisiana; Grenada, Mississippi.

MICRASTERIAS DENTICULATA var. ANGULOSA (Hantz.) W. & G. S. West. — Florida (Brown, 1930).

MICRASTERIAS DENTICULATA var. INTERMEDIA Nordst. (Pl. II, Fig. 9).

— Length 258 μ, width 225 μ, isthmus 32 μ. Sun, Louisiana. New for North America.

MICRASTERIAS DENTICULATA var. TAYLORII Krieg. (Pl. VI, Fig. 5). — Length 214 μ, width 190 μ, isthmus 24 μ. Near St. Tammany, Louisiana. Previously reported from Newfoundland.

MICRASTERIAS DEPAUPERATA var. **convexa,** var. nov.[4] (Pl. V, Figs. 3–4). — A variety with lateral margins convex, sloping from the apical incisions, which are not so deep as in the typical form; with a single blunt spine, instead of the usual bifurcate processes, on the upper lateral margins of the basal lobes, the lateral margin only slightly retuse between the spine and the lower angles, which are not produced but are furnished with two stout, curved teeth, as in the typical plant; sinus narrowly linear and closed from a sharply rounded angle throughout its entire length; length 130–140 μ, width 97–100 μ, isthmus 19.8–20.5 μ. Pond near Leesburg, Florida.

MICRASTERIAS DEPAUPERATA var. KITCHELII (Wolle) W. West (Pl. III, Fig. 5). — Length 124–127 μ, width 114–116 μ, isthmus 24–25 μ. Hickory, Louisiana. Rare. New for the region.

MICRASTERIAS FIMBRIATA Ralfs (f.) (Pl. IV, Fig. 5). — Length 237–244 μ, width 203–209 μ, isthmus 26–30 μ. Alabama (Brown, 1930); Florida; Covington, Bogalusa, Louisiana; Magnolia, Summit, Pascagoula, Mississippi.

This species shows a great deal of variation in the number and arrangement of the spines, which intergrade between those of the typical form and those of var. *spinosa* Biss. In the Mississippi plants a number of expressions appear, none of which agree with the typical plant because of the lack of spines within the apical margin of the polar lobe.

MICRASTERIAS FIMBRIATA var. SPINOSA Biss. (f.) (Pl. IV, Figs. 1–4, 9). — Length 206–237 μ, width 178–181 μ, isthmus 28.5 μ. Audubon Park, New Orleans, Louisiana; Pascagoula, Mississippi.

[4] *Micrasterias depauperata* var. **convexa,** var. nov. — Varietas marginibus lateralibus convexis, declivibus ab incisionibus apicalibus, quae non tam profundae quam in typica forma; unica spina obtusa in marginibus lateralibus superioribus loborum basalium vice solitorum processuum bifurcatorum; margine laterali vix retusa inter spinam angulosque inferiores, qui non producti sunt sed duobus dentibus crassis curvatis velut in planta typica praediti; sinu anguste lineari atque per totam longitudinem clauso et ab angulo abrupte rotundato egrediente. Long. 130–140 μ, lat. 97–100 μ, lat. isth. 19.8–20.5 μ.

Like the preceding form, this variety shows a modification in respect to the spines within the apical margin of the polar lobe.

MICRASTERIAS FLORIDENSIS var. **spinosa,** var. nov.[5] (f. *spinosa* Whelden, 1941, p. 269) (Pl. III, Fig. 10). — A variety similar to the typical plant except that there are three or four stout spines within the upper and lower margins of the lateral lobes and within the lateral margin of the polar lobe; length 172 μ, width 162 μ, isthmus 18 μ. Small lake in city park, Eustis, Florida.

MICRASTERIAS FOLIACEA Bail. (Pl. III, Figs. 6–7). — Length 136–170 μ, width 82–83.5 μ, isthmus 14.5–16 μ. Alabama (Brown, 1930); Hickory, Louisiana. New for the region.

MICRASTERIAS FURCATA Ralfs. — Florida (Bailey, 1851; Brown, 1930).

MICRASTERIAS FURCATA var. SIMPLEX Wolle. — Florida (Wolle, 1892).

MICRASTERIAS INCISA De Bréb. — Florida (Bailey, 1851).

MICRASTERIAS JENNERI Ralfs (Pl. II, Fig. 8). — Length 157–164 μ, width 112–115 μ, isthmus 26 μ. Picayune, Mississippi. New for the region.

MICRASTERIAS JENNERI var. SIMPLEX W. West (Pl. II, Figs. 5, 11; Pl. V, Fig. 9). — Length 82–164 μ, width 105–115 μ, isthmus 26 μ. Pearl River, Louisiana; Picayune, Mississippi. New for the region.

Both the typical form and var. *simplex* W. West are very rare in the Gulf region. Whenever this species appears it is accompanied by several others, in a highly acid habitat. Plate V, Figure 9, shows an expression which combines the marginal incisions of the typical plant and the smooth wall and polar lobe of var. *simplex* W. West.

MICRASTERIAS JOHNSONII W. & G. S. West. — Florida (W. and G. S. West, 1898).

MICRASTERIAS JOHNSONII var. RANOIDES (Salisb.) Krieg. (Pl. I, Fig. 18). — Length 198 μ, width 216 μ, isthmus 18 μ. Pond near Osteen, Florida.

This species and its variety *ranoides* (Salisb.) Krieg. have never been reported from anywhere except Florida.

[5] *Micrasterias floridensis* var. **spinosa,** var. nov. — Varietas typicae plantae similis praeterquam quod habet tres vel quattuor spinas crassas intra margines loborum lateralium superiores inferioresque atque intra margines lobi polaris laterales. Long. 172 μ, lat. 162 μ, isth. 18 μ.

MICRASTERIAS LATICEPS Nordst. — Florida; ditch near Baker, Slidell, Louisiana; small pond near Magnolia, lake near Dixie Springs, Summit, Mississippi.

MICRASTERIAS LATICEPS var. CRASSA Presc. (f.) (Pl. II, Figs. 2, 6). — Length 108–133 μ, width 114–141 μ, isthmus 23 μ. Lateral lobes higher than in the typical form; sinus narrower, closed for one half its length. Sorrento, Louisiana; Waveland, Mississippi. New for the region.

MICRASTERIAS MAHABULESHWARENSIS Hobs. (Pl. I, Figs. 9, 12; Pl. III, Fig. 12; Pl. VI, Fig. 6). — Length 125–160 μ, width 95–130 μ, isthmus 18–26 μ. Pond near Osteen, Florida; Sorrento, Lac des Allemands, Louisiana; lake near Dixie Springs, 4 miles north of Summit, Mississippi.

This plant intergrades with some of the expressions of *Micrasterias americana* (Ehr.) Ralfs to such an extent that it would seem logical to combine these two species.

MICRASTERIAS MAHABULESHWARENSIS var. DICHOTOMA G. M. Smith (Pl. I, Fig. 8; Pl. V, Fig. 10). — Length 133.2 μ, width 126 μ, isthmus 21 μ. Lake Minneola near Groveland, Florida. New for the region.

MICRASTERIAS MAHABULESHWARENSIS var. RINGENS (Bail.) Krieg. (Pl. V, Fig. 8). — Length 129 μ, width 111 μ, isthmus 21.6 μ. Royal Palm Park, Florida. Coll. Ruth Patrick.

MICRASTERIAS MURICATA (Bail.) Ralfs (Pl. I, Fig. 4). — Length 166 μ, width 106 μ, isthmus 19–20 μ. Generally distributed in many habitats throughout Florida, Louisiana, and Mississippi. Always found with other species of Micrasterias. New for the region.

MICRASTERIAS NOVAE-TERRAE (Cushm.) Krieg. (Pl. I, Fig. 10). — Length 128–135 μ, width 98–110 μ, isthmus 11 μ. Pond near Osteen, Florida. New for the region.

MICRASTERIAS OSCITANS Ralfs (Pl. II, Fig. 14). — Length 150 μ, width 118 μ, isthmus 23 μ. Florida; Picayune, Mississippi.

MICRASTERIAS OSCITANS var. MUCRONATA (Dix) Wille (f.) (Pl. II, Fig. 10). — Length 137 μ, width 112 μ, isthmus 30 μ. Pearl River, Louisiana. New for the region.

MICRASTERIAS OSCITANS var. MUCRONATA (Dix) Wille (f.) (Pl. II, Fig. 13). — Length 128 μ, width 120 μ, isthmus 28 μ. Pearl River, Louisiana.

This form is intermediate between the typical plant and var. *mucronata* (Dix) Wille. The polar lobe is similar to that of the species, but the high dorsal margins of the lateral lobes, with a tendency to have mucrones, are characteristics of the variety.

MICRASTERIAS PAPILLIFERA De Bréb. — Florida (Bailey, 1851; Wood, 1874).

MICRASTERIAS PAPILLIFERA var. SPECIOSA (Wolle) Krieg. (Pl. V, Fig. 11). — Length 112–120 μ, width 108 μ, isthmus 14.5 μ. Sphagnum swamp near Pearl River, Louisiana; Florida.

MICRASTERIAS PINNATIFIDA (Kuetz.) Ralfs (Pl. I, Figs. 13, 17). — Length 62 μ, width 72 μ, isthmus 15 μ. In ponds and ditches throughout Florida, Louisiana, and Mississippi.

This species shows considerable variation, but the varieties do not seem to appear in the same habitat, which suggests that the plant is very responsive to varying chemiophysical environmental conditions.

MICRASTERIAS PINNATIFIDA var. QUADRATA Bail. — Florida (Bailey, 1851).

MICRASTERIAS PIQUATA Salisb. (Pl. II, Fig. 17). — Length 106–111 μ, width 83–96 μ, isthmus 17–19 μ. Pond near Bay St. Louis, ditch near Magnolia, Mississippi; Florida.

MICRASTERIAS PIQUATA f. **picayunensis,** f. nov.[6] (Pl. I, Fig. 3). — A form larger than the typical one; polar lobe strongly convex and not at all emarginate, as it is in the species, and higher, separated from the lateral lobes by a wider incision, the dorsal margins of the lateral lobes being almost horizontal; sinus usually more widely open outwardly; length 128–151 μ, width 105–123 μ, isthmus 25–30 μ. Covington, Hickory, Louisiana; Picayune, Mississippi.

MICRASTERIAS RADIATA Hass. (Pl. I, Fig. 16; Pl. V, Fig. 1). — Length 95 μ, width 162 μ, isthmus 25 μ. Widely distributed and common in collections from Florida, Louisiana, and Mississippi.

Plate I, Figure 16, shows one of the many forms of this species. Plate V, Figure 1, illustrates an abnormal cell which possesses a

[6] *Micrasterias piquata* f. **picayunensis,** f. nov. — Forma maior quam typica; lobo polari valde convexo, haud emarginato velut in specie; lobo polari altiore et a lobis lateralibus incisione latiore separato, marginibus dorsalibus loborum lateralium paene horizontalibus; sinu exteriore in parte plerumque latius aperto. Long. 128–151 μ, lat. 105–123 μ, lat. isth. 25–30 μ.

semicell of the typical plant and one similar to those of var. *gracillima* G. M. Smith.

MICRASTERIAS RADIATA var. DICHOTOMA (Wolle) Cushm. (Pl. III, Fig. 1). — Length 159–165 μ, width 152–165 μ, isthmus 20.5 μ. Slidell, Louisiana. Very abundant in one collection. New for the region.

MICRASTERIAS RADIATA var. GRACILLIMA G. M. Smith (Pl. III, Fig. 3). — Length 145–160 μ, width 135–148 μ, isthmus 16 μ. Hickory, Lacomb, Louisiana; Pearlington, Summit, Mississippi. New for the region.

MICRASTERIAS RADIOSA Ralfs (Pl. III, Fig. 4; Pl. IV, Figs. 13–14). — Length 196 μ, width 189 μ, isthmus 20 μ. Alabama; Titusville, Florida; Goodbee, Louisiana; Summit, Magnolia, Pearlington, Mississippi.

MICRASTERIAS RADIOSA var. ACULEATA Krieg. (f.) (Pl. VI, Fig. 7). — Length 235 μ, width 234 μ, isthmus 18 μ. Magnolia, Mississippi. New for North America.

This plant has some characteristics of var. *aculeata* Krieg., but lacks spines (as does the typical form) except at the apex of the polar lobe, which is furnished with two pairs of aculei similar to those of the variety. We have not seen enough specimens to determine whether this is a distinct and constant expression.

MICRASTERIAS RADIOSA var. ELEGANTIOR G. S. West (f.) (Pl. III, Fig. 9; Pl. IV, Figs. 11–12). — Length 231–241 μ, width 222–238 μ, isthmus 24–25 μ. Oakhill, Florida; Sun, Louisiana; Magnolia, Summit, Mississippi.

This plant has a great many varieties of expression in our collections. In Plate IV, Figures 11–12, are shown some plants which have polar lobes like those of var. *elegantior* G. S. West, but which do not have spines within the lateral margins of the lobes.

MICRASTERIAS RADIOSA var. **extensa**, var. nov.[7] (Pl. IV, Figs. 7–8,

[7] *Micrasterias radiosa* var. **extensa**, var. nov. — Varietas lobis polaribus ultra lobos laterales paululum extensis; marginibus lateralibus lobi polaris ⅔ longitudinis a basi subparallelis deinde abrupte divergentibus necnon apicem latum margine dorsali concavo efficientibus; angulis lateralibus lobi polaris in spinam brevem productis, et spinam crassam extrorsus divergentem sitamque admodum intra marginem angulorum lateralium eius habentibus; margine ventrali semicellulae atque marginibus lobulorum undulatis; sinu in exteriore parte late aperto,

10). — A variety with polar lobes somewhat extended beyond the lateral lobes, the lateral margins of the polar lobes subparallel for three fourths of their length from the base and then diverging abruptly to form a broad apex, which has a concave dorsal margin; the lateral angles of the polar lobe extended into a short spine, with a stout, outwardly diverging spine just within their margin; ventral margin of the semicell and margins of the lobules undulate; sinus widely open outwardly, gradually narrowing to a rounded angle; basal lobules extended much beyond the length of the other lobes and generally terminating in a single process rather than a bifurcate one; a row of spines usually present within the ventral margins of the semicell, along the lateral margins of the polar lobe, and along the upper margins of the lateral lobes; length 200 μ, width 272 μ, isthmus 20 μ. Pearl River, Louisiana.

MICRASTERIAS RADIOSA var. ORNATA Nordst. (Pl. III, Fig. 8). — Length 143–231 μ, width 136–222 μ, isthmus 15.5–24 μ. Lumberton, Magnolia, Summit, Mississippi. New for the region.

MICRASTERIAS ROTATA (Grev.) Ralfs (Pl. III, Fig. 11; Pl. IV, Fig. 6). — Length 253–297 μ, width 237–261 μ, isthmus 32 μ. Magnolia, Summit, Mississippi.

This differs from the usual form in the absence of spines and in the shallower denticulations of the lobules.

MICRASTERIAS SUBOBLONGA var. **maxima**, var. nov.[8] (Pl. I, Fig. 7). — A variety larger than the typical one; cell oblong; the polar lobe broadly convex at the apex, margin of the lateral lobes convex to the basal angles, which are rounded and tipped with a blunt spinelike protuberance; sinus narrowly linear from a slightly rounded angle; length 143 μ, width 102 μ, isthmus 33 μ. Picayune, Mississippi.

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ad angulum rotundatum gradatim attenuato; lobulis basalibus multo longius aliis lobis productis, et plerumque in extrema parte processum unicum potius quam bifurcatum efficientibus; plerumque ordine spinarum intra margines ventrales semicellulae et secundum margines laterales lobi polaris loborumque lateralium superiorum. Long. 200 , latμ. 272 μ, lat. isth. 20 μ.

[8] *Micrasterias suboblonga* var. **maxima**, var. nov. — Varietas maior quam planta typica; cellula oblonga; lobo polari in apice late convexo, margine loborum lateralium convexo, angulis basalibus rotundatis praefixisque protuberatione obtusa spiniformi; sinu anguste lineari et ab angulo paululum rotundato egrediente. Long. 143 μ, lat. 102 μ, lat. isth. 33 μ.

This plant is similar to the much smaller var. *australis* Krieg. and should be compared with it.

MICRASTERIAS TETRAPTERA var. **protuberans,** var. nov.[9] (Pl. V, Figs. 5–6). — A variety larger than the typical one; polar lobe broader and strongly bilobed, the apical margin concave and the lateral angles furnished with three short spines along the dorsal margin; membrane spiny within the margins of the polar lobe and the upper lateral lobes and along the ventral margin of the semicell, a prominent median swelling at the base of the semicell; sinus narrowly linear throughout its entire length; length 138–146 μ, width 135–138 μ, isthmus 18.5–20 μ. Pond near Leesburg, Florida.

This variety is similar, in general, to var. *Taylorii* Krieg., especially in the shape of the polar lobe, but var. *Taylorii* has no spines and there are no protuberances at the base of the semicells.

MICRASTERIAS TETRAPTERA var. TAYLORII Krieg. (f.) (Pl. VI, Fig. 1). — Length 75.6–79 μ, width 60–68 μ, isthmus 12–14.5 μ. Rice-fields near Carville, Louisiana. New for the region.

MICRASTERIAS TORREYI Bail. — Length 250–410 μ, width 450 μ, isthmus 27 μ. Pond near Osteen, Florida.

MICRASTERIAS TORREYI var. NORDSTEDTIANA (Hier.) Schm. (f.) (Pl. III, Fig. 2). — Length 325 μ, width 285–290 μ, isthmus 28.8 μ. Pond near Osteen, Florida. New for North America.

In our specimens the apices of the lobules have bifurcations with short rounded tips.

MICRASTERIAS TRIANGULARIS Wolle (Pl. II, Figs. 15–16). — Length 216–232 μ, width 108–184 μ, isthmus 30 μ. Picayune, Mississippi. New for the region.

MICRASTERIAS TRUNCATA (Corda) De Bréb. (Pl. II, Fig. 7). — Length 125 μ, width 112 μ, isthmus 20 μ. Alabama (Brown, 1930); widely distributed in Florida, Louisiana, and Mississippi.

This plant shows numerous variations, many of which have been named. It appears to be one of the desmid species which is

[9] *Micrasterias tetraptera* var. **protuberans,** var. nov. — Varietas maior quam planta typica; lobo polari latiore atque valde bilobato, margine apicali concavo, angulis lateralibus tribus spinis brevibus secundum marginem dorsalem praeditis; membrana spinosa intra margines lobi polaris loborumque lateralium superiorum et secundum marginem ventralem semicellulae, inflatione prominente media ad basim semicellulae; sinu anguste lineari per totam longitudinem. Long. 138–146 μ, lat. 135–138 μ, lat. isth. 18.5–20 μ.

able to adapt itself to a great variety of limnological factors. It is found in habitats ranging from a pH of 6.2 to one of 7.4.

MICRASTERIAS TRUNCATA var. **convexa**, var. nov.[10] (Pl. II, Fig. 3). — A variety somewhat smaller than the typical one; cells subcircular to oblong in outline, the poles broadly convex or sometimes flattened and slightly retuse in the median portion; sinus narrowly linear and closed throughout its entire length; semicells three-lobed, the lateral incisions very slight, being only one fourth the depth of the polar incisions, which are narrow and almost horizontal; the lateral lobules furnished with three toothlike projections at the angles; lateral angles of the polar lobe broadly rounded and relatively much deeper than in the other varieties, furnished with three prominent toothlike projections on the lateral and dorsal margins; length 57–136 μ, width 57–112 μ, isthmus 26 μ. Bonfouca, Louisiana; Picayune, Mississippi.

The recurved margins of the polar lobe and the height of this lobe from the ventral to the dorsal margin separate this plant from the other described varieties.

MICRASTERIAS TRUNCATA var. PUSILLA f. **cuneata**, f. nov.[11] (Pl. II, Fig. 12). — A circular form with a broadly rounded apex that is produced laterally and tipped with a single stout spine which is either horizontal or curved upward; polar lobe cuneate, incisions below the polar lobe moderately wide from broadly rounded angles, the ventral margins of the polar lobe and the

[10] *Micrasterias truncata* var. **convexa**, var. nov. — Varietas aliquantulum minor quam planta typica; cellulis subrotundis ad oblongas variantibus, polis late convexis aut interdum complanatis atque in media portione paululum retusis; sinu anguste lineari perque totam longitudinem clauso; semicellulis 3-lobatis, incisionibus lateralibus admodum brevibus, solum ¼ longitudinis incisionum polarium, his angustis atque paene horizontalibus; lobulis lateralibus ad angulos tribus projectionibus dentiformibus praeditis; angulis lateralibus lobi polaris late rotundatis atque relative multo profundioribus quam in varietatibus aliis, in marginibus lateralibus dorsalibusque projectionibus prominentibus dentiformibus praeditis. Long. 57–136 μ, lat. 57–112 μ, lat. isth. 26 μ.

[11] *Micrasterias truncata* var. *pusilla* f. **cuneata**, f. nov. — Forma rotunda, apice late rotundato qui lateraliter productus est atque una spina crassa aut horizontali aut sursum curvata praefixus; lobo polari cuneato, incisionibus infra lobum polarem paulum latis et ab angulis late rotundatis egredientibus, marginibus ventralibus lobi polaris atque marginibus superioribus loborum lateralium undulatis subparallelisque; semicellula 5-lobata, duobus lobis lateralibus in duos lobulos, in duobus angulis crassa spina praefixos, divisis; sinu anguste lineari atque clauso, triente exteriore longitudinis excepto, qua in parte paululum apertus est. Long. 56–58 μ, lat. 57 μ, lat. isth. 10 μ.

upper margins of the lateral lobes undulate and subparallel; semicell five-lobed, the two lateral lobes divided into two lobules, which are tipped at each of their two angles with a stout spine; sinus narrowly linear and closed except in the outer third of its length, where it is slightly opened; length 56–58 μ, width 57 μ, isthmus 10 μ. Everglades, Florida; Slidell, Louisiana.

Micrasterias truncata var. quadrata Bulnh. (Pl. I, Fig. 1). — Length 125 μ, width 112 μ, isthmus 22 μ. Picayune, Mississippi. New for North America.

Micrasterias truncata var. semiradiata (Naeg.) Cleve (Pl. II, Fig. 4). — Length 85 μ, width 98 μ, isthmus 49 μ. Ditch near Atchafalaya Spillway, Louisiana. New for the region.

Micrasterias truncata var. tridentata Krieg. (f.) (Pl. I, Fig. 2). — Length 130 μ, width 112 μ, isthmus 26 μ. Picayune, Mississippi; Montreal, Canada (Irénee-Marie, 1938).

This variety seems to agree with var. *tridentata* Krieg. except that the angles of the polar lobe are not bifurcate, as in the originally described plant.

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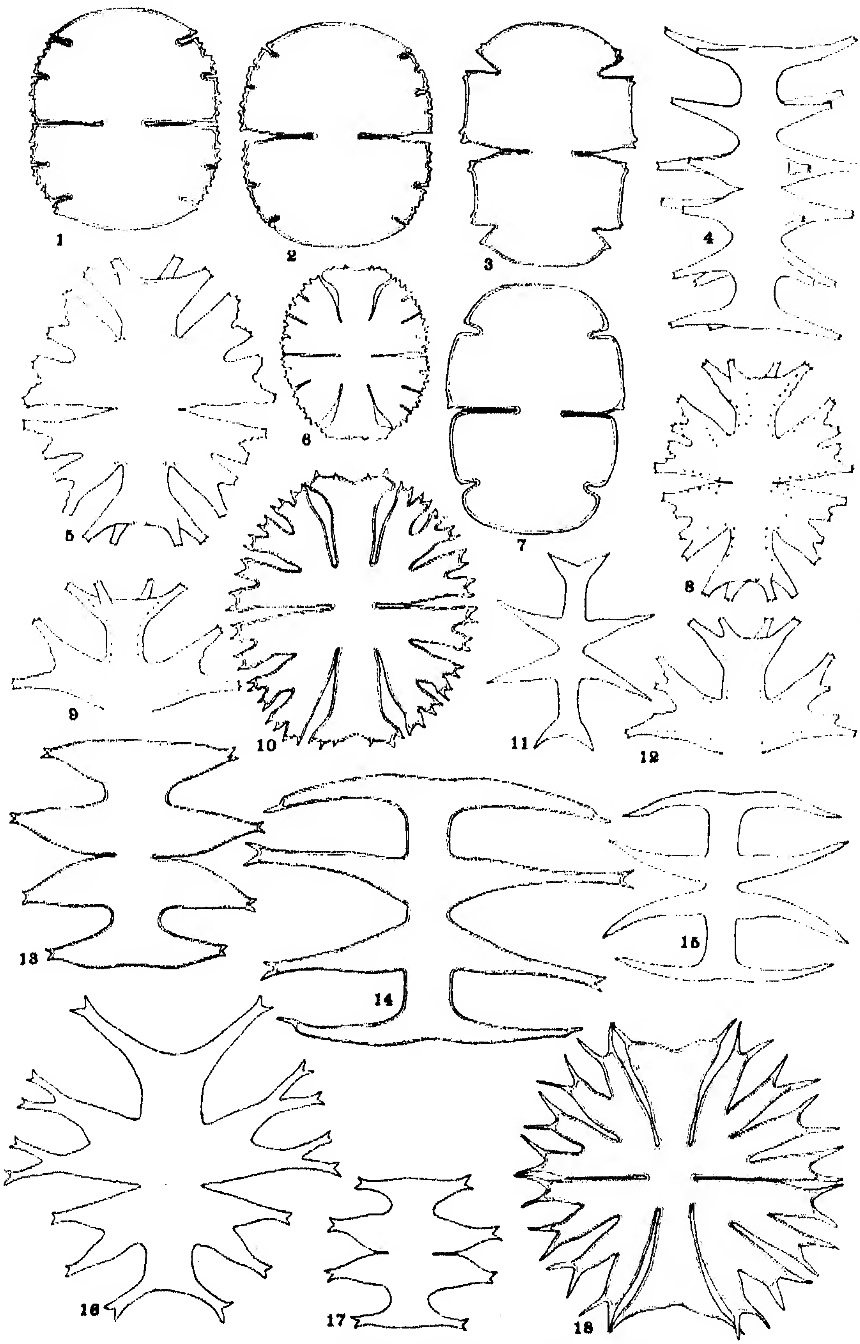
PLATES I–VI

EXPLANATION OF PLATE I

1. Micrasterias truncata var. quadrata Bulnh.
2. M. truncata var. tridentata Krieg., f.
3. M. piquata f. picayunensis, f. nov.
4. M. muricata (Bail.) Ralfs
5. M. americana (Ehr.) Ralfs, f.
6. M. conferta var. hamata Wolle
7. M. suboblonga var. maxima, var. nov.
8. M. mahabuleshwarensis var. dichotoma G. M. Smith
9. M. mahabuleshwarensis Hobs.
10. M. novae-terrae (Cushm.) Krieg.
11. M. arcuata var. expansa (Bail.) Nordst.
12. M. mahabuleshwarensis Hobs.
13. M. pinnatifida (Kuetz.) Ralfs
14. M. arcuata var. lata, var. nov.
15. M. arcuata var. gracilis W. & G. S. West
16. M. radiata Hass., f.
17. M. pinnatifida (Kuetz.) Ralfs
18. M. Johnsonii var. ranoides (Salisb.) Krieg.



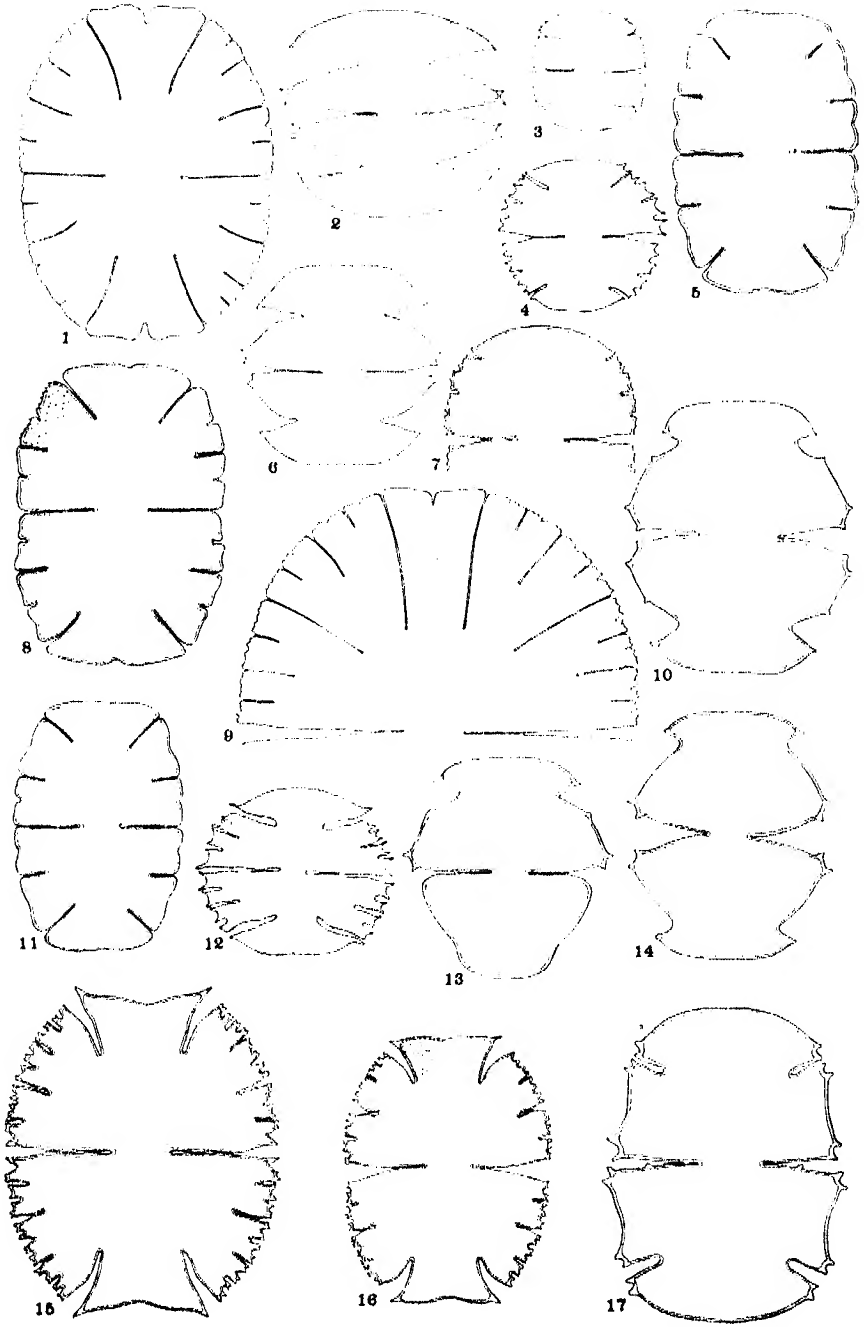
Desmids from the southeastern United States

EXPLANATION OF PLATE II

1. Micrasterias denticulata De Bréb., f.
2. M. laticeps var. crassa Presc., f.
3. M. truncata var. convexa, var. nov.
4. M. truncata var. semiradiata (Naeg.) Cleve
5. M. *Jenneri* var. *simplex* W. West
6. M. laticeps var. crassa Presc., f.
7. M. truncata (Corda) De Bréb.
8. M. Jenneri Ralfs
9. M. denticulata var. intermedia Nordst.
10. M. oscitans var. mucronata (Dix) Wille, f.
11. M. Jenneri var. simplex W. West
12. M. truncata var. pusilla f. cuneata, f. nov.
13. M. oscitans var. mucronata (Dix) Wille, f.
14. M. oscitans Ralfs

15-16. M. triangularis Wolle

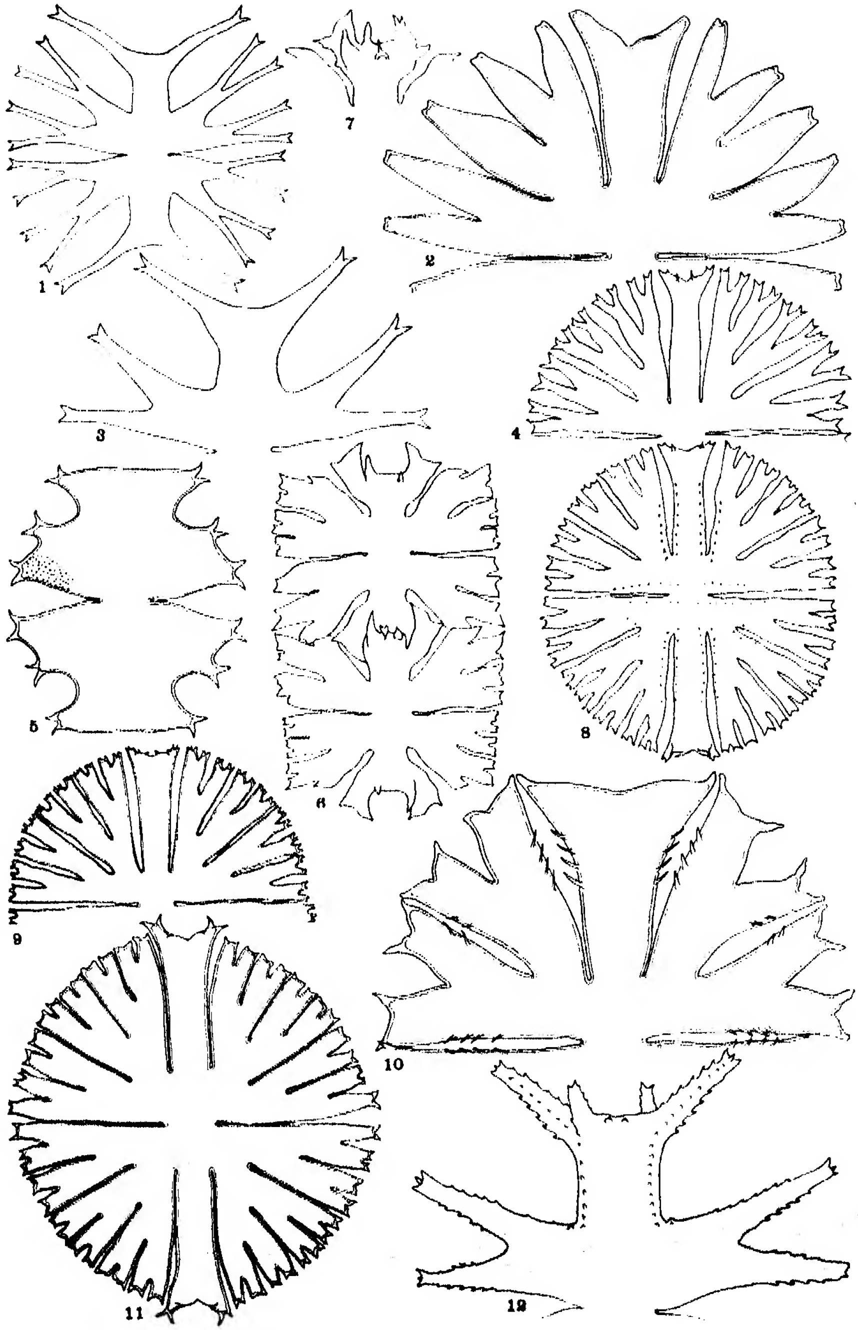
17. M. piquata Salisb.



Desmids from the southeastern United States

EXPLANATION OF PLATE III

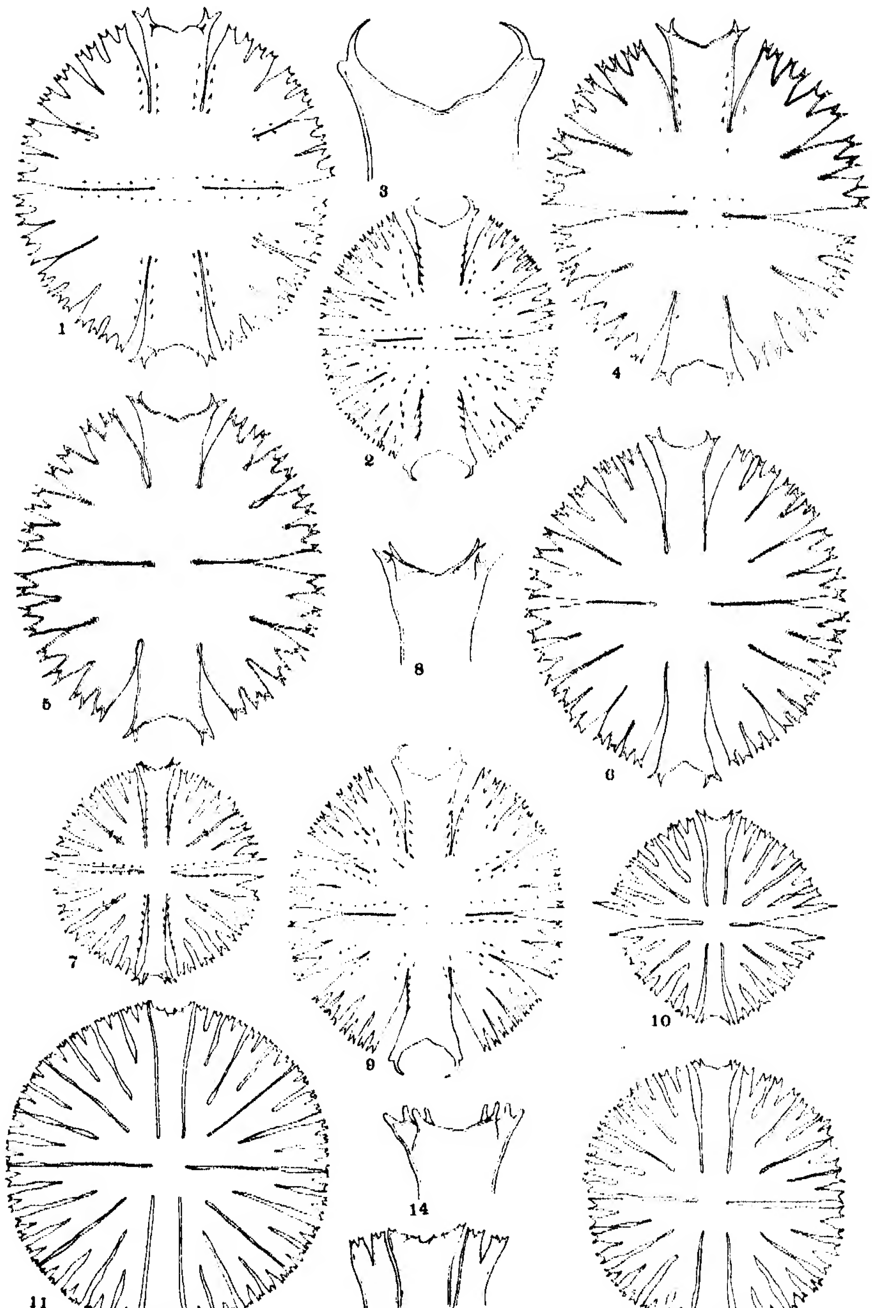
1. Micrasterias radiata var. dichotoma (Wolle) Cushm.
2. M. Torreyi var. Nordstedtiana (Hier.) Schm., f.
3. M. *radiata* var. *gracillima* G. M. Smith
4. M. radiosa Ralfs
5. M. depauperata var. Kitchelii (Wolle) W. West
6. M. foliacea Bail.
7. M. foliacea Bail., detail of apical region, polar lobe
8. M. radiosa var. *ornata* Nordst.
9. M. radiosa var. elegantior G. S. West, f.
10. M. floridensis var. spinosa, var. nov.
11. M. rotata (Grev.) Ralfs
12. M. mahabuleshwarensis Hobs.



Desmids from the southeastern United States

EXPLANATION OF PLATE IV

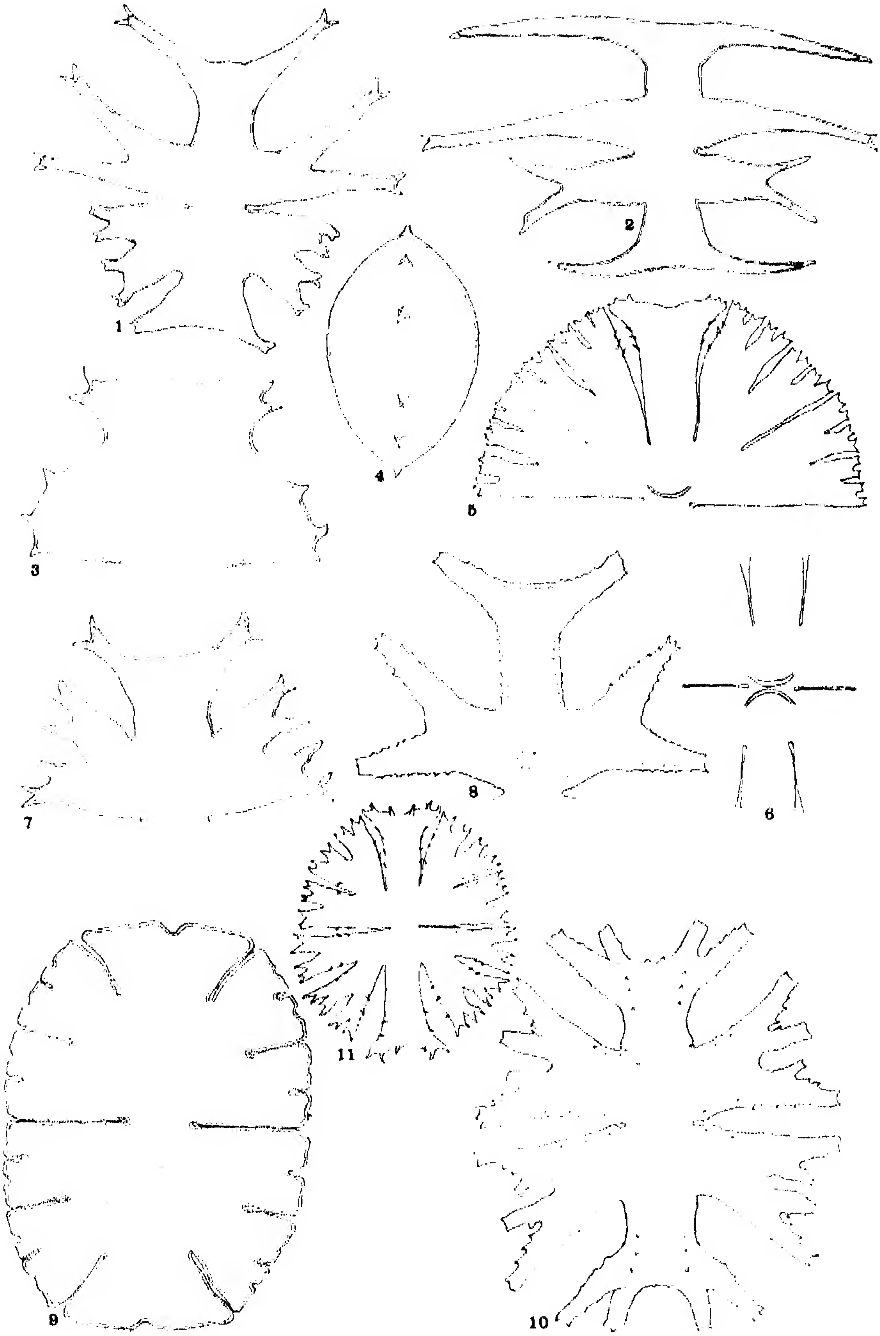
1 2. Micrasterias fimbriata var. spinosa Biss.
3. M. fimbriata var. spinosa Biss., f., detail polar lobe
4. M. fimbriata var. spinosa Biss., f.
5. M. fimbriata Ralfs, f.
6. M. rotata (Grev.) Ralfs
7. M. radiosa var. extensa, var. nov.
8. M. radiosa var. extensa, var. nov., detail polar lobe
9. M. fimbriata var. spinosa Biss., f.
10. M. radiosa var. extensa, var. nov.
11. M. radiosa var. elegantior G. S. West, f.
12. M. radiosa var. elegantior G. S. West, f., detail polar lobe
13. M. radiosa Ralfs
14. M. radiosa Ralfs, detail polar lobe



Desmids from the southeastern United States

EXPLANATION OF PLATE V

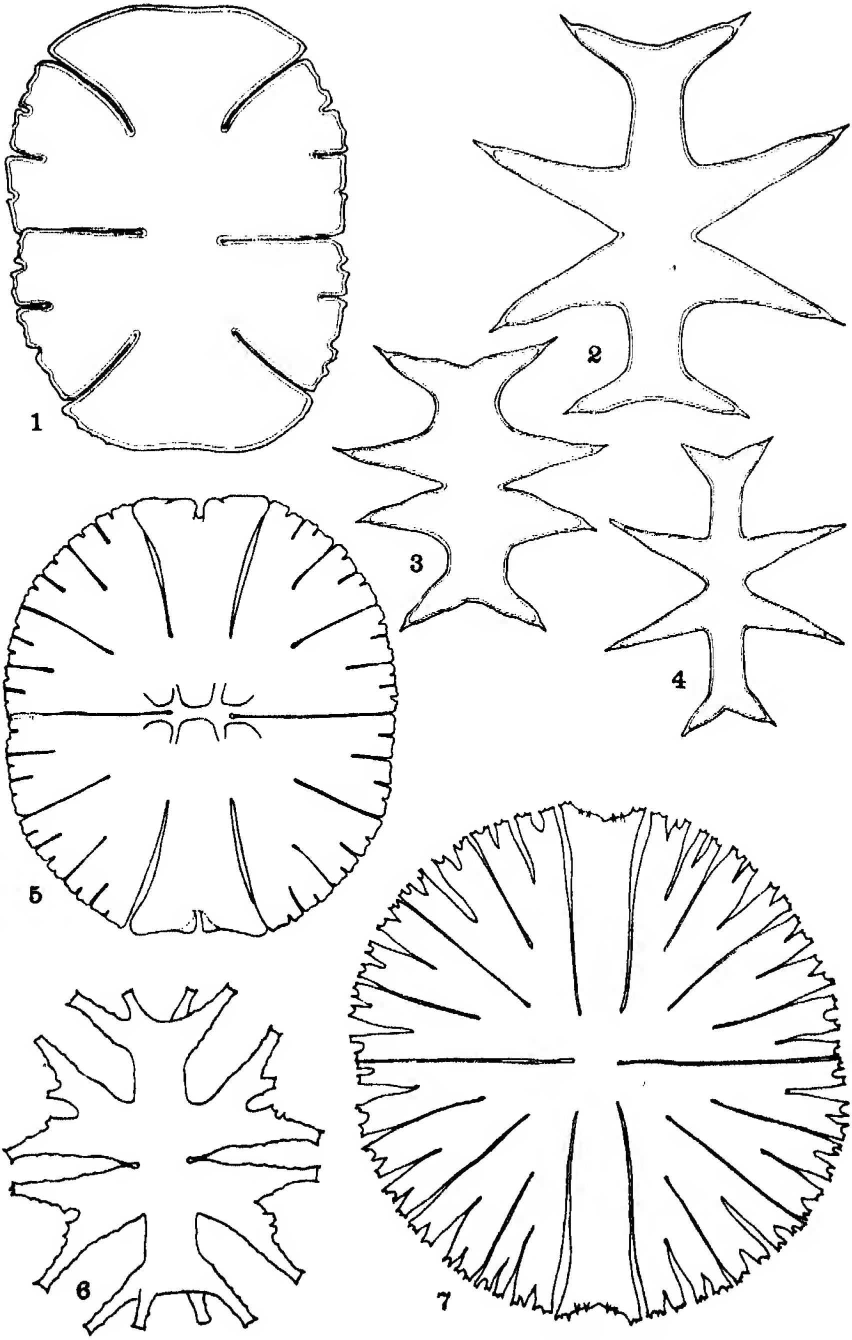
1. Micrasterias radiata Hass., abnormal semicell approaching var. pseudocrux Grönbl.
2. M. arcuata var. lata, var. nov.
3-4. M. depauperata var. convexa, var. nov.
5. M. tetraptera var. protuberans, var. nov.
6. M. tetraptera var. protuberans, var. nov., detail mid-region
7. M. crux-melitensis (Ehr.) Hass.
8. M. mahabuleshwarensis var. ringens (Bail.) Krieg.
9. M. Jenneri var. simplex W. West
10. M. mahabuleshwarensis var. dichotoma G. M. Smith
11. M. papillifera var. speciosa (Wolle) Krieg.



Desmids from the southeastern United States

EXPLANATION OF PLATE VI

1. Micrasterias tetraptera var. Taylorii Krieg., f.
2. M. arcuata var. expansa (Bail.) Nordst.
3. M. arcuata var. robusta Borge
4. M. arcuata var. expansa (Bail.) Nordst.
5. M. denticulata var. Taylorii Krieg.
6. M. mahabuleshwarensis Hobs., f.
7. M. radiosa var. aculeata Krieg., f.



Desmids from the southeastern United States

A MONOGRAPH ON THE GENUS LEUCOPAXILLUS BOURSIER *

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IN THE Friesian classification of the agarics the genera Tricholoma and Clitocybe are separated by the manner in which the gills are attached to the stipe. In the former they are characterized as sinuate or emarginate, whereas in the latter they are described as broadly adnate or decurrent. At first glance this appears to be a fairly sharp separation, but in practice it has not been so useful as one might expect it to be. In fact, on the basis of this distinction certain forms so closely related that we have included them as varieties within a species in the following account have previously been grouped in different genera. A study of the specimens prepared by Karsten, Peck, Kauffman, and others has further demonstrated to us that previous investigators often disagreed concerning the generic disposition of a given species. The present monograph is designed to clear up some of the confusion noted above. By segregating certain of the border-line species in the genus Leucopaxillus not only does the classical distinction between Clitocybe and Tricholoma become much more precise, but a number of obviously very closely related species are brought together in an arrangement that is both practical and natural. In spite of the emphasis given to chemical and anatomical characters in the definition of the genus that follows, experience has proved that it is easy for a skilled collector to recognize the Leucopaxilli in the field by their macroscopic characters. Surely no critical students of agarics, not even those who are averse

* Contribution from the Laboratory of Cryptogamic Botany and the Farlow Herbarium No. 211, Harvard University, and the Herbarium of the University of Michigan.

to changes in the system of classification used in gill fungi, will deny that in this instance the study of the fungi grouped here has been made much simpler and much more logical than it was under the Friesian system.

The diagnostic characters of the genus can be briefly summarized as follows: Pileus generally rather fleshy and unpolished, the surface more or less fibrillose under a lens, the margin usually inrolled, tomentose at least when young, and frequently ribbed or grooved; gills close to crowded and variable in the manner of their attachment — from somewhat sinuate to distinctly decurrent; stipe fleshy to fibrous-fleshy and quite firm; spores white in mass, either *smooth* or *verrucose* and *amyloid;* pleurocystidia absent; clamp connections present.

Boursier (1) established the genus for *Clitocybe paradoxa* C. & D. and *Tricholoma pseudoacerbum* C. & D. Previously the species now arranged in Leucopaxillus have been distributed in Clitocybe (*C. albissima, paradoxa, piceina, subhirta, amara, pulcherrima, rhodoleuca, candida*) and Tricholoma (*T. laterarium, pseudoacerbum, tricolor, lentum*) as well as in genera like Pleurotus (*P. nauseosodulcis*) and Paxillus (*P. giganteus*).

In 1887 Patouillard (8) segregated the rough-spored species of Clitocybe in the genus Lepista. In 1887, however, and again in 1900 he (9) defined Lepista as including only the species of the section Inversae of Clitocybe (*C. gilva, C. inversa*, and others believed to be rough-spored). Since *C. gilva* was the first species mentioned, it should be regarded as the type of the genus Lepista. Since its spores are not amyloid, the name "Lepista" cannot be applied to the species here placed in Leucopaxillus, even though at least one species of the latter (*L. amarus*) was later placed in Lepista by Patouillard. On this basis the name "Lepista," in the sense of Patouillard, does not have priority over the name "Leucopaxillus," but instead becomes a synonym of Clitocybe.

In 1924 Maire (7) referred the Leucopaxilli to Lepista, and recently Konrad and Maublanc (4, Vol. VI) reduced Leucopaxillus to the rank of a subgenus of Lepista. Maire (6), however, abandoned his earlier view in 1934, when, with Kühner, he studied the iodine reactions of the spore walls of the white-spored genera of the Agaricineae. Kühner (5) himself had adopted Leucopaxillus as an autonomous genus as early as 1926. In 1934 Kühner and Maire (6) also

created a new genus, Aspropaxillus, for the species with amyloid but smooth spores. Since these species had essentially the same characters in other respects, Singer (11) emended the genus Leucopaxillus to include *Clitocybe candida*, *C. gigantea* (= *Paxillus giganteus*), and *C. lepistoides*. He also pointed out that the presence of clamp connections formed an additional distinguishing character of the genus.

When we began the study presented in this monograph the following species were already known to belong in Leucopaxillus: *Clitocybe albissima* Peck, *C. amara* Fr., *C. candida* Bres., *C. paradoxa* C. & D., *C. piceina* Pk., *C. rhodoleuca* (Rom.) Sacc., *Lepista barbara* Maire, *Paxillus giganteus* Fr., *Tricholoma pseudoacerbum* C. & D., and *T. tricolor* Peck. We are adding *C. albiformis* Murrill, *C. pulcherrima* Peck, *C. stipitata* Murrill, *C. subhirta* Peck, *Melanoleuca bicolor* Murrill, *M. oreades* Murrill, *M. roseibrunnea* Murrill, *Pleurotus nauseosodulcis* (Karst.) Sacc., *Tricholoma laterarium* Peck, *T. lentum* (Romell) Sacc., *T. brasiliense* Rick, and *Leucopaxillus gracillimus* S. & S. There has been no previous attempt to study the species of Leucopaxillus from the flora of a particular region or to monograph them.

We wish to express our appreciation to Dr. H. D. House, state botanist of New York, for the privilege of studying the collections of Dr. Charles H. Peck. These collections are preserved at the New York State Museum, Albany, New York. We are also indebted to Dr. F. J. Seaver, of the New York Botanical Garden, for access to the collections of Dr. W. A. Murrill; to Dr. E. B. Mains for the use of Kauffman's notes and the collections in the University of Michigan Herbarium; and to Dr. David H. Linder for access to the various collections deposited in the Farlow Herbarium of Harvard University.

For aid in carrying out part of the field work we gratefully acknowledge the courtesies extended to the senior author by Dr. Ralph T. King, director of the Roosevelt Wildlife Forest Experiment Station, Huntington Forest, Newcomb, New York, and grants made to the junior author by the Horace H. Rackham School of Graduate Studies of the University of Michigan. These grants rendered possible the field work along the Pacific coast that contributed in a large measure to the completeness of this investigation, as well as expeditions to the Great Smoky Mountains National Parks.

DEFINITION AND LIMITS OF THE GENUS

The genus Leucopaxillus is determined by the following characters: The spores are amyloid, pure white in prints on white paper, hyaline under the microscope, small to medium-sized ($< 10\ \mu$), ellipsoid to ovoid or subglobose, without a smooth suprahilar spot and either smooth or roughened (not truly echinulate). The amyloid character of the spore wall must be determined by examining the spores under a microscope in daylight. The preparation is first treated with ammonia for a few seconds or minutes. The ammonia is then extracted and replaced by Melzer's reagent (iodide of potassium 1.5 gr.; iodine 0.5 gr.; distilled water 20.0 gr.; chloral hydrate 20.0 gr.). If the spore walls turn slate violet or dark violet they are amyloid. Nonamyloid spores stay hyaline or become yellowish, and so-called pseudoamyloid spores become intensely reddish brown. Slightly amyloid spores like those of *Leucopaxillus candidus*, *L. giganteus*, and *L. lepistoides* are kept in the medium for a short time (about 15 minutes). The coloration in these species is observed more clearly wherever the spores are in groups.

The hyphae bear numerous easily demonstrable clamp connections and have thin walls that may or may not be incrusted with a pigment and that are decidedly nonamyloid. The gill trama is regular to somewhat interwoven, and in old specimens the cells are rather irregular in diameter. The subhymenium is thin or very thin and ramose.

The basidia have so far been found to be almost constantly four-spored, not granulose in acetocarmin, and not in any way distinctive in either size or shape. Pleurocystidia and pseudocystidia are not differentiated. Cheilocystidia may be lacking, scattered, or numerous. The cuticle of the pileus consists of a compact layer of narrow subcylindric more or less appressed hyphae, from which scattered oblique or erect hyphae project.

The carpophores are of medium or very large size, thick, fleshy, soft or tough, with a dry context but not leathery. If vascular hyphae are present, they are not colored by sulfoformol. The lamellae are usually sinuate or decurrent but never free. They are often readily separable, however, from the context of the pileus. The stipe is solid, fibrous and fleshy, rather firm to very firm, but never cartilaginous or fistulose, and never brittle or waxy.

The margin of the pileus is never pellucid-striate, but rather frequently short-ribbed to crenulate from early contact with the lamellae at the time the margin is still strongly inrolled. There are no veils, and the development is gymnocarpic, as has been shown by Kühner (5) for *L. tricolor*.

The chemical reactions with ordinary reagents (alkali, acids, formol, phenol, aniline) are weak and not distinctive. In some species the reaction to guaiac is positive. In *L. albissimus* var. *typicus* methylparamidophenol gives a positive reaction only on the margin of the cap and on the lamellae.

The habitat is usually in woods on humus or around very decayed logs, on soil under brush, or on grassy ground near trees. The carpophores usually occur in rings or in irregular groups (gregarious), and apparently the species do not form mycorrhiza.

This definition excludes all genera with nonamyloid spores (Clitocybe, Tricholoma, Paxillus, etc.); all genera and species without clamp connections, with spores having a suprahilar smooth spot and cystidia in the hymenium (Melanoleuca); all genera or species with one or more veils (*Armillaria luteovirens* — "*Melanoleuca portolensis*," as it is described — the species of Catathelasma, Cystoderma, etc.); all genera with free lamellae (those belonging to the Amanitaceae and Leucocoprinaceae); all forms with colored spores and nonregular gill trama (like Paxillus, which is nearer the Boletaceae); all genera with more highly differentiated surface layers on the pileus (Marasmius, Delicatula, Lepiotella, Cystoderma, Hebelomina, etc.); the species of the genus Lentinellus with numerous lactifers that stain in sulfoformol and protrude into the hymenium in the form of pseudocystidia; all species with amyloid tramal hyphae (part of Marasmius, Lentinellus, etc.); and, finally, all genera with Omphalia-like shape and stipe, of thin, cartilaginous, brittle, or waxy consistency and ordinarily fistulose stipes, thin diaphanous or hygrophanous margin of the pileus, and generally small stature (pileus $<$ 30 mm. broad).

Although the genus Leucopaxillus is unquestionably a natural group within the Tricholomataceae, it is by no means isolated. There are a few species of Clitocybe and Tricholoma (*C. maxima* and *T. mongolicum*) that come rather near to *L. giganteus* and its closely related species. Although we fully recognize this relationship, we believe that the amyloid reaction of the spore wall here constitutes a

very usable as well as a natural character by which to distinguish Leucopaxillus from both genera.

The exclusion of "*Melanoleuca*" *portolensis* Murrill from *Leucopaxillus* is tentative, and eventually it may appear desirable to emend our definition of the genus to include veiled species. Singer studied the type of Murrill's species, but could find no traces of a veil. Since the type is in very poor condition, not much reliance can be placed on the absence of veil remnants, and it is evident that fresh material will have to be found in order to classify the species properly. The following anatomical data were obtained by Singer from his study of the type: spores $5.5–7.8 \times (3.5)\ 4–4.3\ (-\ 5)\ \mu$, not strongly but nevertheless distinctly amyloid, hyaline, smooth or very indistinctly uneven, with very thin walls (the unevenness may be due to slight wrinkles in the thin spore wall resulting from incomplete reviving), granulose within and often with a small central droplet. Basidia $27–36 \times 5.3–7\ \mu$. Cystidia and cheilocystidia none. Gill trama probably regular, with rather broad hyphae. Hyphae of the cuticle of the pileus appressed and smooth, without an incrusting pigment over their membranes, quite variable in diameter ($2.3–21\ \mu$), probably not parallel and often with claviform ends. All hyphae bear clamp connections, and in many the walls are up to $1\ \mu$ thick.

If there is really a veil, as is stated in the original description, *M. portolensis* should probably be placed in the genus Armillaria, as restricted by Singer, and in the neighborhood of *Armillaria luteovirens.* Better material is needed, however, to decide this question, since the most important difference between Armillaria sensu stricto and Leucopaxillus consists in the structure of the gill trama and the subhymenium. Since it has been shown that *Tricholoma mirabile* Bres., which is also described as having a veil, belongs in Melanoleuca sensu stricto (non Murrill), there is, theoretically, no reason for excluding veiled species from Leucopaxillus if they do not differ from that genus in other characters.

There is still another small group of species, including *Omphalia Kalchbrenneri* Bres. and its American relatives, that seem to be rather close to Leucopaxillus anatomically, but approach Omphalia externally. They may be interpreted — as they were by Singer (13) for *O. Kalchbrenneri* — as belonging to a section of Xeromphalina Kühner & Maire, characterized by amyloid spores and no pleurocystidia or cheilocystidia, or they may be considered to be a very

sharply separated subgenus of Leucopaxillus containing the small omphaloid species. This group has been excluded from the present account because it clearly represents a phylogenetic series entirely distinct from those now included in Leucopaxillus.

COMMENTS ON THE CHARACTERS OF THE SPECIES

The species of Leucopaxillus are very closely related to one another. In fact, part of them represent smaller taxonomic units than the average conception of a species in the agarics. Because of this the study of the material had to be carried out very carefully, and, since most species from Europe and Africa as well as from the eastern or the western United States have been described under different names, we have tried to compare specimens — wherever possible the type specimens or authentic material — from all these regions.[1] In some only very small differences were found to distinguish these original forms. In general, those from the western United States were more like the European and Asiatic representatives than were those from the eastern part of the United States. Lack of sufficient material has prevented us, however, from assuming the existence in Leucopaxillus of geographic races or subspecies in the sense of Singer (14). We are treating these forms, more cautiously, as varieties until further studies on their distribution establish the proper area for each. Certain described species have been regarded as forms in this work because the typical forms grow in the same territory and no differentiation into races has been found to be likely in them. The characteristics distinguishing them are considered due largely to environmental factors.

Generally speaking, the taste (whether bitter or mild), the quantity of pigment (not its location), the degree of decurrence of the lamellae on the apex of the stipe, and the absolute size of the carpophores are characters that are believed to have no value for the delimitation of species in Leucopaxillus, and we have used them to distinguish only the varieties and forms.

Characters that do have a general or limited value for the delimitation of species are:

[1] In the paragraphs "Material studied" the following abbreviations are used: FH = Farlow Herbarium, Harvard University; Mich. = Herbarium of the University of Michigan; NY = New York Botanical Garden; NYS = New York State Museum (Albany, New York); LE = Cryptogamic Herbarium of the Academy of Science in Leningrad.

1. *The degree of the amyloid reaction of the spore wall as well as the degree of roughness.* — There are two groups of species in Leucopaxillus that differ only in these characters. So far as we know now, a correlation exists between the ornamentation of the spore wall and its chemical composition. The smooth spores are very slightly amyloid, and generally become so only in a certain stage of development (some spores apparently always remain nonamyloid). In species that, under an oil-immersion lens, are seen to have a warty spore surface, the spores always exhibit a strong amyloid reaction. The reason for this apparent correlation is simple. The part reacting the strongest with iodine is the perisporal disrupted layer of the membrane, whereas the subjacent thin main wall does not react with iodine in young spores, and it does so only very slightly in older ones. Since we have found no transitions between the smooth and the warty types of spore, we are using the character for the main division of the genus into two sections: (1) Aspropaxilli (Kühner and Maire, as genus Aspropaxillus, 1934) with smooth spores, and (2) Eu-Leucopaxilli sect. nov. (= Leucopaxillus sensu Boursier and Maire) with warty spores.

2. *Color and type of pigment (if present).* — A very peculiar pigment is found in *L. tricolor;* it changes upon drying or when subjected to different chemical treatments. The incrustation of the walls of the hyphae by a brown membrane pigment in *L. amarus* is also very characteristic. A more unstable pigment is observed in *L. pulcherrimus.* Here the substance is dissolved in the cell sap. The pigment that gives the pale buff to pale incarnate color to certain other species, such as *L. laterarius,* is likewise dissolved in the cell sap.

3. *Frequence of the cheilocystidia.* — *L. amarus* and its forms have rather numerous cheilocystidia. In *L. brasiliensis* they appear to be rather numerous, but in the dried material available for our study they were so incrusted with a dark vinaceous substance that accurate observation of them was greatly hindered. Certain authors have considered the gill edge of *L. amarus* to be heteromorphous, but since many fertile basidia occur among the cheilocystidia, we can describe it at best as only "almost heteromorphous." Scattered cheilocystidia of the same type as those in *L. amarus* are occasionally found in other species not mentioned above.

4. *Size of the spores.* — Careful measurements of the spores of all species of Leucopaxillus (the ornamentations are included in the

dimensions given in our descriptions) show that the character is not very important. It is valuable in only a few species. In *L. laterarius*, *L. gracillimus*, and *L. brasiliensis* the spores do not measure more than 5.5 μ in length, and thus they aid in distinguishing these species. *L. barbarus* was described by Maire as having relatively large spores (we have had no opportunity to verify his measurements, but as a rule they are remarkably exact). Small spores are characteristic of *L. amarus*, and *L. lepistoides* is distinguished from *L. candidus* and *L. giganteus* by its slightly longer spores. In *L. albissimus* var. *subhirtus* the size of the spores was found to vary extremely, from 4 to 7 μ long in one preparation.

5. *Thickness of the subhymenium.* — All species studied by the authors themselves (i.e. all except one of those included in this paper) have very thin ramose subhymenia. R. Maire, however, attributes a more voluminous subhymenium to the species we have not studied, *L. rhodoleucus*.

6. *Attachment of the lamellae and the shape of the inner ends of the lamellulae.* — Although the attachment of the lamellae at the stipe is rather inconstant in some species, especially in *L. albissimus* and *L. amarus*, in others it is relatively constant. *L. tricolor*, *L. laterarius*, and *L. lepistoides* are rather "tricholomoid" in this respect, whereas *L. candidus*, *L. giganteus*, and *L. rhodoleucus* are decidedly "clitocyboid." In the latter three the lamellulae are gradually attenuated, in contrast to the other species, in which the inner ends of the lamellulae are mostly abruptly rounded or very sharply attenuated from a particular level. Sometimes they appear emarginate, and thus resemble the gills of *Armillaria luteovirens*.

7. *Chemical reactions.* — Reactions like those of guaiac and methylparamidophenol may be of some importance in future studies on Leucopaxilli. At present, however, our material is insufficient to allow us to draw any definite conclusions.

Concerning the evolution of the species of Leucopaxillus, there cannot be any doubt which of the two sections is the more primitive. In the Aspropaxilli not only is the amyloid reaction of the spores, a character of the more highly evolved forms, less evident than in the Eu-Leucopaxilli, but also the pigmentation and the uniform structure of the hymenium belong to a more simple type of development. There seems to be great variability in the forms of the *giganteus* group

rather than a complex of highly specialized and localized forms or races, such as has been observed in the more recently evolved group. In addition, the connection with other genera is more evident in the Aspropaxilli. All groups approaching the genus Leucopaxillus to such a degree that they can be considered related to it have smooth spores. *Omphalia Kalchbrenneri*, "*Melanoleuca*" *portolensis*, and *Clitocybe fellea* sensu Kauffman all have smooth spores and therefore cannot be compared with the Eu-Leucopaxilli. Further, it should be noted that the number of species is considerably less in the Aspropaxilli than in the Eu-Leucopaxilli.

Only in Europe and North America have sufficient studies been made to indicate the relative abundance of Leucopaxilli in the agaric flora. From a study of dried material Singer discovered that there were two South American species among Rick's Brazilian agarics. At the present time the known species are distributed in South America (Brazil), in North America from California to Florida and north into Canada, and in the Eastern Hemisphere from northern Scandinavia to French North Africa. In addition, *L. amarus* has been found in South Africa. *Clitocybe eucalyptorum* Clel. (the reaction of the spores in iodine is not known) from Australia probably belongs here also. In the Altai Mountains of Asia *L. candidus* has been collected up to the timber line (Singer, 12). In the Caucasian Mountains *L. amarus* (f. *typicus*) has been reported by Singer (11), and *L. candidus*, *L. amarus*, and *L.* (*albissimus* var.) *paradoxus* by Vassilieva (15). R. Maire, in several lists, reported *L.* (*albissimus* var.) *paradoxus*, *L. barbarus*, *L. rhodoleucus*, and *L. lepistoides* for North Africa. All but one of the species and varieties reported for Africa and Asia have also been observed in either Europe or North America. Out of a total of eighteen species and varieties of Leucopaxillus thirteen have been observed in North America, eight in Europe, five in Africa, three in Asia, two in South America, and one (?) in Australia. Further investigations will doubtless add a number of species from South America, Australia, Asia, and Africa, but on the basis of present data North America appears to be the center of distribution for the genus.

KEY TO SPECIES

I. Aspropaxilli: spores smooth, slightly amyloid

A. Lamellae decurrent, lamellulae not abruptly rounded; stipe not grayish in old specimens or in properly prepared exsiccati; lamellae arcuate and rather narrow

1. Lamellae white, eventually becoming merely sordid or pallid; old pilei whitish .... 1. *L. candidus*

2. Lamellae if white at first soon with a creamy or buff tint and eventually becoming almost alutaceous; old pilei cream buff to chamois .... 2. *L. giganteus*

B. Lamellae mostly and at least partially sinuate or emarginate; lamellulae rather abruptly rounded; stipe grayish in old specimens; lamellae subventricose in the marginal third, rather broad (up to 12 mm.) .... 3. *L. lepistoides*

II. Eu-Leucopaxilli: spores more or less warty, very strongly amyloid

A. Cheilocystidia scattered or absent, pigment of pileus lacking or not incrusting the walls of the hyphae of the cuticle with dark reddish-brown areolae, warts or rings

1. Lamellae white, rarely yellow or pinkish, never becoming vinaceous to purplish brown in dried condition

a) Pileus without hygrophanous spots. Subhymenium thin, (about one third to one half the diameter of the hymenium); lamellae white or creamy, rarely yellow

(1) Pileus never with a pinkish flush and never bright yellow, but pure white to cream-color or pale buff, pale tan, etc. At least some of the spores measuring longer than 5.5 μ when mature. Taste bitter or mild. On needles or on leaves or on anthills

(a) Stipe normal (central), not on anthills ... 4. *L. albissimus*

(b) Stipe long, eccentric, arising from anthills. Odor fetid in drying. Taste sweetish but disagreeable 5. *L. nauseosodulcis*

(2) Pileus, stipe and context under cuticle yellow. Spores 4–5.8 μ long. Taste mild. On humus under hardwoods 6. *L. pulcherrimus*

(3) Pileus ordinarily with a flush of pink, sometimes white. Spores never larger than 5.5 μ. Taste decidedly bitter. On humus under hardwoods .... 7. *L. laterarius*

b) Pileus with hygrophanous spots when fresh. Subhymenium rather thick (about three fourths the diameter of hymenium). Lamellae at first pinkish or pinkish white .... 8. *L. rhodoleucus*

2. Lamellae distinctly yellow, pale yellow, sulphur or cream-color, becoming vinaceous to purplish brown in dried specimens

a) Pileus dark violet, ashy green around margin ... 9. *L. brasiliensis*

b) Pileus pinkish buff to dull tan .... 10. *L. tricolor*

B. Cheilocystidia numerous. Hyphae of the cuticle of the pileus more or less incrusted by a brown or reddish-brown pigment, which forms warts, areolae, or rings on the hyphal walls. Hyphae rarely not incrusted

1. Stipe 8–15 (40) mm. thick .... 11. *L. amarus*

2. Stipe 2 mm. ± thick .... 12. *L. gracillimus*

SECTION I: ASPROPAXILLI (MAIRE) S. & S.

1. *Leucopaxillus candidus* (Bres.) Singer, Rev. d. Mycologie, 4:68. 1939

Clitocybe candida Bres. Fung. Trid., 1:16, pl. 18. 1882. Icon. Myc., 4:172. 1928.

(?) *Agaricus giganteus* Sibthorp, Flora Oxon., p. 420. 1794. Sowerby, Engl. Fung., pl. 244. 1800.

Illustration: Bresadola, *l. c.*

Pileus 60–200 mm. broad, convex or somewhat flattened at first, becoming somewhat depressed in age, glabrous but at first pubescent at the involute margin (rarely faintly squamulose in some Altaian specimens), smooth or rarely (in some Altaian collections) ribbed-crenulate at the margin, white, later very pale and dirty brownish white, especially in the center, sometimes becoming buff-colored (particularly in drying); context white, firm, odor weak, farinaceous or spermatic (like that of *Inocybe geophylla*), taste agreeable, mild; lamellae white, becoming pallid or dirty white, narrow, easily separable from the context of the pileus, crowded to close; stipe 40–80 mm. long, 20–35 mm. thick, equal or sometimes slightly ventricose, pure white (at least at the apex and base in the younger plants), remaining white or becoming very pale dirty brownish white, surface smooth or more rarely coarsely scaly downward, usually distinctly furfuraceous-squamulose or pubescent-scurfy at the very apex.

Spores pure white in mass, 6.5–8 × 3.3–4.5 μ, hyaline, smooth, some very slightly or distinctly but never strongly amyloid, some (probably the younger ones) nonamyloid, ellipsoid, with little or no depression; basidia 22–40 (45) × 5–7.7 μ, four-spored; cheilocystidia none; gill trama more or less regular, consisting of filamentous hyphae about 4 μ thick, lactiferous hyphae occasionally found among them; hyphae of the scales of the stipe 2.5–5 μ thick; cuticle of the pileus compact, of interwoven, appressed, thin-walled hyphae 2.3–8.8 μ thick, clamp connections regularly present.

Habitat. — In open mixed woods and in subalpine meadows near conifer trees; also in coniferous woods among needles and on grassy soil, mostly in the mountains up to the timber line (where it is found under Larix). Gregarious, often in large fairy rings. July-October.

Distribution. — In the Alps in Europe and in the Caucasus and

Altai Mountains in Asia. Other localities mentioned in the literature need confirmation. See "Observations."

Material studied. — Authentic material from Trento, coll. and det. Bresadola (NY). Two collections of fresh specimens from the mountains around the Kurai Step, Oirotia, near the Mongolian border, coll. and det. Singer (LE). Specimens from the Caucasian Reservation, Malaya Laba River, coll. Vassilieva, det. Singer (LE).

Observations. — This species is very close to *L. giganteus* (Fr.) Singer, but can be distinguished from it by the color of the gills of mature or old fruiting bodies. Bresadola indicated that his species occurred in North America also. This statement was probably based on a specimen that he identified and that is now preserved in the Farlow Herbarium. The spores are not amyloid and, consequently, it cannot be placed in Leucopaxillus. The only American material likely to belong to *L. candidus* was collected by Smith in Michigan. Since the specimen is rather small and was found in a quite different habitat, it probably is more accurately identified as a young stage of *L. giganteus.* Its microscopic characters allow such a disposal of it. It would not be surprising to find *L. candidus* in the Pacific coast states, but at present we have no records of its occurrence in that area.

2. *Leucopaxillus giganteus* (Fr.) Singer, Schweiz. Zeitschr. Pilzk., 17 : 14. 1939

Agaricus (Clitocybe) giganteus Fr., Monogr., p. 118. 1857 (A. Peterson, Monogr. Clit., p. 22. 1854).
Paxillus giganteus Fr., Hymen. Eur., p. 401. 1874.
Clitocybe gigantea Quélet, Champ. Jura et Vosges, 1 : 88, pl. 3, fig. 3. 1872.
Omphalia geotropa gigantea Quélet, Enchir. Fung., p. 23. 1886.
Aspropaxillus giganteus Kühner & R. Maire, Bull. Soc. Myc. Fr., 50 : 13. 1934.
Melanoleuca oreades Murrill, Mycologia, 5 : 218. 1913.

Illustrations:
For the spores see Figure 3 (see p. 100).
Fries, Sver. Ätl. och Gift. Svamp., pl. 86.
Quélet, *l. c.*
Hussey, Illus. Brit. Mycol., pl. 79 (pileus very white).
Barla, Champ. Alp. Mar., pl. 56 (good).
Letellier, Hist. Champ., pl. 682 (good).
Cooke, Illus. Brit. Fung., pl. 150 (106).
Konrad et Maublanc, Icon. Sel. Fung., 3, pl. 290 (good).
Lange, Flora Agar. Danica, pl. 33, fig. F.
(The figures of Sicard, Britzelmayr, and Sowerby are poor or incorrect.)

Pileus 100–450 mm. broad, slightly convex to almost flat, rarely depressed from the beginning, soon becoming depressed over the center and the margin arched, finally infundibuliform, never umbonate, slightly moist at first, drying quickly and not viscid, when young glabrous except for the pubescent-involute margin (surface with the feel of kid), later often more or less rimulose or even faintly squamulose, especially in the center, often grooved at the margin, color creamy-white, soon becoming darker, particularly in the center, varying from about "cream buff" to "chamois" (R.), rarely with pale rusty-brownish places; context white or whitish, watery in old specimens, firm, finally soft in the pileus, odor weak, farinaceous or "mossy" (Quélet), "somewhat suggestive of skunk cabbage" (Murrill), taste mild; lamellae white or more often whitish with a creamy or buffy tint, finally almost alutaceous, crowded to very close, decurrent, narrow (when compared with the thickness of the flesh and diameter of the pileus), 5–13 mm. broad, usually straight, but sometimes crisped, anastomosing and sometimes forked, separable from the pileus, lamellulae subsinuate, attenuate; stipe 45–75 mm. long, 22–50 mm. thick, solid, rather short, equal or irregular, occasionally ventricose or with an inflated base, fibrous and glabrous, smooth or somewhat wrinkled in old specimens, rarely split longitudinally, white to concolorous with the pileus.

Spores pure white in mass, $5.3–8 \times 3–5.7$ μ, hyaline, smooth, ellipsoid to ovoid, mostly without an oil drop, with little or no depression, amyloid (as in *L. candidus* or more distinctly so); basidia $35 \times (5.5)\, 6–6.5\, (8)$ μ, four-spored; cheilocystidia none; gill trama subregular, consisting of interwoven hyphae which are rather thick in mature carpophores (5–15 μ), lactiferous hyphae none or very few.

Habitat. — In open mixed woods and in hilly places under spruce and fir, very often in gardens and parks on grassy soil, mostly in the plains and up to the lower limit of the mountain zone. Gregarious, often in large fairy rings. August-October.

Material studied. — Fresh specimens were obtained from the Forêt de Fontainebleau, France, under oak and conifers at the edge of the woods, coll. and det. Singer; from the region of the Donets River, U. S. S. R. (LE; det. Singer), and from Warrensburg, New York, coll. Smith (Mich.). Type specimen of *Melanoleuca oreades* from Washington (NY). Dried specimens from Whitmore Lake,

Michigan, coll. Kauffman (Mich.); one fruiting body from Kent Lake, Oakland County, Michigan, 1937, coll. Smith (Mich.); from Lyon, France, coll. and det. M. Josserand, 1932 (Mich.).

Observations. — There appears to be no very sharp line of demarcation between *L. giganteus* and *L. candidus*. It is possible that *L. candidus* is only a mountain variety of *L. giganteus*. We consider it unlikely that *L. candidus* is merely the pale immature stage of *L. giganteus*, although many reports of the former in the literature really apply to the young stages of the latter. It is surprising to find the colored species called *giganteus* Sowerby in all manuals and mycological papers up to the present time. An examination of Sowerby's publication shows that he did not describe the plant as new, but referred instead to Sibthorp, *Flora Oxonensis*, and expressed some doubt whether his fungus was really identical with *Agaricus giganteus* Sib., which Sibthorp described as a wholly white agaric, with a citation of Buxbaum, who described a similar large white species from Duderhof, near St. Petersburg (Leningrad), Russia. An accurate disposition of all these descriptions and illustrations is difficult, but they appear to apply to what is now called *L. candidus* rather than to the fungus Fries placed in Agaricus or *Paxillus giganteus*. Indeed, Fries was the first to interpret the species of Sibthorp as the colored agaric we now know as *Leucopaxillus giganteus*. He also appears to have been the first to give the wrong citation — *A. giganteus* Sow. Since, however, agaric nomenclature officially starts with Fries, we are using what seems to be his concept and are citing him as the original authority.

Kauffman (3) included *Clitocybe gigantea* in the Michigan flora, but gave the size of the spores as 5×3 μ. Smith's collection from the Adirondacks was also characterized by rather small spores — 5–6.5 μ. From our study it appears that in American material the spores are usually closer to the lower edge of the range given, and that in European specimens they are near the upper edge of the range. The difference appears to be too slight, however, to justify erecting forms or varieties. One other variation we noted was that in European material there is a tendency for the margin of the pileus to be ribbed or grooved a little more regularly than in American material, but here again we may be dealing merely with variations between collections. Kauffman emphasized the ribbed character of the margin of the pileus in his description.

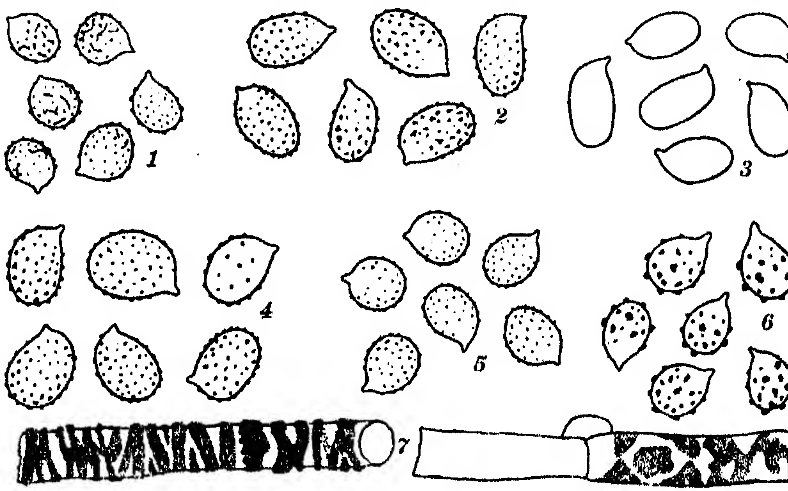
3. *Leucopaxillus lepistoides* (R. Maire) Singer, Schweiz. Zeitschr. Pilzk., 17 : 14. 1939

Tricholoma lepistoides R. Maire, Bull. Soc. Myc. Fr., 40 (4) : 301. 1926.
Aspropaxillus lepistoides Kühner & Maire, Bull. Soc. Myc. Fr., 50 : 13. 1934.

Illustrations: R. Maire, *l. c.*, pls. 19 and 20, fig. 1.

(*a*) Description of the African material (from Maire, *l. c.*):

Pileus white, then with greenish-gray spots near the center, finally often tinged with pale ochraceous, glabrous but sometimes



FIGURES 1–7

FIG. 1, spores of *L. laterarius;* FIG. 2, spores of *L. albissimus* var. *paradoxus* f. *albiformis;* FIG. 3, spores of *L. giganteus;* FIG. 4, spores of *L. tricolor;* FIG. 5, spores of *L. amarus* f. *typicus;* FIG. 6, spores of *L. pulcherrimus;* FIG. 7, hyphae from cuticle of *L. amarus* f. *typicus*

The figures were drawn with the aid of a camera lucida and as reproduced are magnified approximately 1650 times.

becoming slightly scaly from appressed scales on the margin, opaque (reminding one of kid when touched), very slightly viscid, then dry, with a more or less separable cuticle and a sterile involute margin, which soon becomes merely incurved, thick, not very acute, faintly tomentose, smooth and not wavy; convex then flattened, not or only a little depressed in the center, very fleshy, 100–200 mm. in diameter; context white, sometimes blue within at the base, more

or less soft and spongy, fleshy in the pileus, fibrous-fleshy in the stipe, odor like anise, very specific, taste mild; chemical reaction: guaiac –, HNO_3 –, CH_3CO_2H –, H_2SO_4, surface of young pileus pinkish gray, old pileus olive ochre, blue context of the base of the stipe yellow; lamellae whitish, finally pale tallow color, not anastomosing (except for the rear part), crowded, thin, separable from the context of the pileus, often more or less connate or anastomosing near the stipe, some forked, arched and then somewhat ventricose near the margin, attenuate at the cap margin, rounded or subattenuate at the stipe, sinuate-adnate or a little decurrent, then often adnate-emarginate, broad (up to 12 mm.), lamellulae abruptly rounded and even emarginate at times; stipe white at times, finally becoming slightly grayish, faintly pubescent, then glabrous or scarcely pruinose at the apex, scarcely fibrous-striate, dry, solid, confluent with the pileus, subequal or subbulbous, more or less blunt above a part of the mycelium mixed up with the soil.

Spores 7.5–9 × 4.5–5.5 μ, hyaline, smooth, amyloid (in the original description J–), ellipsoid, with one or several droplets; basidia 30–38 × 7–8 μ, four-spored; cystidia and cheilocystidia none; subhymenium *ramose, thin (one half to one third thickness of* hymenium); gill trama regular, consisting of more or less flexuose hyphae 7–14 μ thick.

Habitat. — Pastures, brushy woods, plantations, under Eucalyptus, Olea, Lentiscus. Solitary to gregarious. Autumn and spring.

Distribution. — Algiers and possibly North America (see the following description).

(*b*) Description of American specimens:

Pileus in the dried condition "light buff" with "Sayal brown" (R.) patches, opaque or somewhat shining, with an abruptly narrowed but fertile margin that shows abruptly narrowed lamellae, glabrous, smooth, convex, large; flesh whitish, not extremely thick; lamellae in dried condition dirty pale yellowish, rather broad, broadest near the margin, with or without very faint anastomosing veins, decidedly sinuate, lamellulae rather abruptly rounded and scarcely tapered at end toward the stipe; stipe smoke gray on the dried plant, smooth, glabrous, solid in upper half, equal, lower half ventricose or bulbous, thick and short (shorter than the diameter of the pileus or even its radius); spores 7.5–9 × 4–5 μ, very slightly amyloid, smooth, ellipsoid, flattened but not depressed on the inner side; basidia

30–35 × 7–8 μ, four-spored; cystidia and cheilocystidia none; subhymenium ramose, thin; gill trama as in *L. giganteus.*

Habitat. — Probably in grassy open woods. November.

Material studied. — Specimens from the Don Valley, Toronto, Ontario, Canada, coll. G. S. Bell (FH).

Observations. — Inasmuch as *L. lepistoides* has been recognized previously only from North Africa, it is very interesting to find a fungus almost identical with it in southeastern Canada. We regard our identification of Bell's specimen as tentative, since we have studied it only in the dried condition and have not seen authentic African specimens. For this reason descriptions of them are given separately.

SECTION II: EU-LEUCOPAXILLI S. & S.

4. *Leucopaxillus albissimus* (Peck) Singer, Schweiz. Zeitschr. Pilzk., 17 : 14. 1939.

Agaricus (Clitocybe) albissimus Peck, Bull. Buffalo Soc. Nat. Sci., 1 (2) : 45. 1873.
Clitocybe albissima Sacc., Syll. Fung., 5 : 158. 1887.
(For other "species" belonging to *L. albissimus* sensu lato see synonymy of the varieties.)

Illustration: None (for illustrations of varieties other than the type variety see under respective varieties).

L. albissimus sensu lato is divided into several varieties, which are keyed out at the conclusion of the treatment of this species. It has been necessary to give here complete descriptive data on all the varieties in order to make them clearly recognizable to other investigators, to bring into sharp focus the amount of segregation that is in progress in this species, and to avoid obscuring slight but constant differences in material from other regions. If only *Clitocybe albissima* and *C. paradoxa* were compared they would be considered independent species. Since, however, we have found a whole series of constant but little-differentiated populations connecting the extreme forms, we were forced to include them all under the oldest name — *L. albissimus.*

(*a*) Var. *typicus*

Pileus (30) 50–60 (70) mm. broad, convex but becoming more or less expanded, margin involute and slightly subtomentose when

young, usually ribbed but sometimes smooth, surface glabrous, smooth or rarely faintly rimose-areolate in age, scarcely shining, pure white, remaining white when dried or very rarely subalutaceous over the disc; context pure white, not watery, soft, unchangeable, odor aromatic and sweet but often weak, taste farinaceous-bitter; lamellae white and staying so even in dried material (if properly dried), crowded, or subcrowded, occasional individuals forked at the base, mostly nonanastomosing, adnate with a decurrent tooth or simply decurrent, some with short riblike proliferations down the apex of the stipe, ribs not anastomosing, moderately broad (up to 6 mm.), lamellulae abruptly rounded at inner extremity; stipe 40–70 mm. long, 7–15 mm. thick, subequal but the base often bulbous with adherent remnants of leaves or needles, white-mycelioid, not strigose, solid, white, subglabrous or somewhat fibrous-scabrous (especially at the apex).

Spores pure white in mass, 5.5–7.5 (8.5) $\times$ 4.2–5.5 μ, hyaline, with isolated strongly amyloid warts 0.3–0.4 μ high, ellipsoid to ovoid, depression slight or absent; basidia 24–36 $\times$ 6.5–8.5 μ, four-spored; pleurocystidia none, cheilocystidia extremely rare or lacking; subhymenium ramose, thin; gill trama subregular, consisting of hyphae 1–5 μ thick, with scattered lactifers, clamp connections abundant; reaction with methylparamidophenol: only the lamellae and the margin of the pileus dark violet.

Habitat. — Mostly in mixed woods on leaves and needles together on the forest floor, sometimes in pure hardwood or conifer stands. Solitary, gregarious, or often in rings. Usually in September.

Distribution. — Eastern part of North America: New York, New Hampshire, Ontario, and Michigan.

Material studied. — Type collection, Croghan, New York (NYS). Fresh material from Huntington Forest, Newcomb, New York, coll. and det. Singer (FH). Dried material from Bow, New Hampshire, coll. Blackford (FH); from Richmond Hill, Ontario, University of Toronto Crypt. Herb. no. 9598 (FH); from Michigan, coll. and det. C. H. Kauffman, Sept. 9, 1906, and Aug. 10, 1909 (Mich.); from Au Train, Michigan, 1932, Mains 32–537, det. Smith (Mich.); from University of Toronto Crypt. Herb. no. 3638, coll. G. S. Bell (Mich.).

Observations. — The typical variety of *L. albissimus* is easily known by its bitter taste, medium size, and persistently pure white

color. The pileus is never pubescent-hairy, and the base of the stipe is never strigose.

(*b*) *Leucopaxillus albissimus* var. **piceinus** (Peck) S. & S., comb. nov.

Clitocybe piceina Peck, Bull. Torr. Bot. Club, 3 (4) : 178. 1904.
Illustration: Kauffman, Agar. Mich., II, pl. 154. 1918.

Pileus (50) 60–100 (250) mm. broad, convex with an inrolled margin when young, plane or nearly so in age, surface dry and unpolished (appearing matted-fibrillose under a lens), margin often irregular and frequently ribbed or grooved, the inrolled portion sometimes tomentose, color whitish or cream-color, often becoming tan over the disc, generally pale sordid-ochraceous in age; context white, unchanging, thick, firm, odor somewhat pungent and unpleasant, taste disagreeable and bitter; lamellae whitish or in age tinged yellowish, rather dark yellow in dried plants, close to subdistant, narrow, readily separable from the context of the pileus and cracking readily transversely in age, short-decurrent or extending down the stipe in anastomosing lines, lamellulae rounded at the inner extremity, stipe 30–80 mm. long, 8–30 mm. thick, often eccentric, when young clavate to somewhat bulbous, but elongating and nearly equal in age, solid and firm but when old becoming spongy within, white or becoming tinged with buff, unpolished or becoming finely fibrillose, especially toward the base, often very markedly strigose, smooth and glabrous in the apical region or faintly fibrillose-pruinose.

Spores white in mass, 5.5–8 × 4.5–5 μ, hyaline, depression lacking or very slight, ellipsoid to ovoid, moderately rough to decidedly warty, the warts about 0.4 μ high and strongly amyloid; basidia 33–41 × 6–8 μ, four-spored; cheilocystidia very scattered, filamentose, 20–32 × 3 μ; subhymenium ramose, thin; gill trama subregular, the hyphae narrow and interwoven.

Habitat. — On needle beds in conifer forests, rarely on logs. Kauffman reported this species as growing under maple, but his specimens are labeled "in mixed woods." The types and all material of Murrill, collected in the Adirondacks, grew in conifer habitats. Gregarious, scattered, or solitary. September-October.

Distribution. — Nova Scotia, Adirondack Mountains of New York, Ontario, Michigan, Illinois, Oregon, and Tennessee.

Material studied. — Peck's type from Chicago, on spruce needles, coll. W. S. Moffat and L. H. Watson (NYS). Numerous collections from the Adirondack Mountains, New York, all on coniferous débris or under conifers. (Even specimens whose habitat is described as "under maple" have needles of balsam, spruce, hemlock, or pine in the débris adhering to the stipe.) Coll. and det. (as *Melanoleuca albissima*) by W. A. Murrill (NY; NYS). The following collections from the University of Michigan Herbarium have also been studied: Kauffman, Elkmont, Tennessee, Sept., 1916; Adirondacks, New York, Sept. 10, 1914, and Sept. 1, 1921; Takilma, Oregon, Dec. 10, 1925; Detroit, Michigan, Aug., 1905; Marquette, Michigan, Sept., 1906; G. S. Bell, Aug., 1932, University of Toronto Crypt. Herb. no. 3621, Ontario; Smith and Wehmeyer, Sept., 1931, Nova Scotia; L. C. C. Krieger, Kelly Herb. no. 1566, Ontario; Mains, Aug., 1932, Michigan; Smith, Sept., 1929, Michigan.

Observations. — This variety is distinguished from the others by the bitter taste together with yellowish tints on old and dried specimens. The anastomosing ridges at the apex of the stipe are found to be fairly constant and when present aid materially in identifying specimens.

(*c*) *Leucopaxillus albissimus* var. **subhirtus** (Peck) S. & S., comb. nov.

Agaricus (Clitocybe) subhirtus Peck, Ann. Rep. New York State Mus., 32:25. 1880.

Clitocybe subhirta Peck, Bull. New York State Mus., 1 (2): 11. 1888.

Illustration: none.

Pileus 25–75 mm. broad, convex, soon more or less expanded and sometimes becoming slightly depressed, never infundibuliform, surface dry and somewhat hirsute, especially near the margin, becoming glabrous, margin involute but regular and even, color pale yellowish buff becoming paler in age; context whitish; odor unknown; taste bitter; lamellae whitish or pale yellowish, dull yellow in dried specimens, close to crowded, rather narrow, adnate or more often decurrent, sometimes with faint ridges or lines extending down the apex of the stipe (but not so long as in var. *piceina* and not anastomosing); stipe 25–50 mm. long, 6–10 mm. thick (about as long as the pileus is wide), subequal or thickened downward, stuffed

(or hollow; see Peck), whitish, concolorous with the pileus in dried plants, glabrous except for a velutinous zone at the lamellae, base not strigose but attached to leaves by a copious white mycelium.

Spores 4–7 × 3.5–5.5 μ, hyaline, ellipsoid or ovoid to subglobose, rough or with scattered warts (warts up to 0.5 μ high and strongly amyloid), depression slight or absent; basidia 23–32 × 5.5–6.5 μ, four-spored; cheilocystidia not found; gill trama slightly interwoven to more or less regular, the hyphae varying in size (1) 2–9 (12.5) μ thick; hairs of the pileus thin-walled, hyaline, smooth, more or less cylindric; hyphae of the context with clamp connections.

Habitat. — On humus in frondose woods. July-September.

Distribution. — New York to Ohio.

Material studied. — The type collection from Brewertown, New York, and one other authentic collection (both at NYS). Dried specimens from Oxford, Ohio, coll. and det. (as *Clitocybe albissima*) by Bruce Fink (FH).

Observations. — This variety is rather near to the preceding, but differs in the characters of the apex of the stipe and in the tomentose pileus. There may also be a difference in the variability of the spore size, and there appears to be a constant difference in habitat. In addition, the mycelium at the base of the stipe in var. *subhirtus* is softer than that of var. *piceinus* and is snow white.

(*d*) *Leucopaxillus albissimus* var. **Kauffmanii** S. & S., var. nov.

Pileo albido, glabro praeter marginem valde pubescentem, levi, depresso; lamellis alutaceoflavis in siccitate atque 3 mm. ± latis, haud anastomosantibus, simplicibus, profunde decurrentibus. Sporis 4–7.4 × 3.2–6 μ, magnitudine et forma variabilibus, amyloidibus, verrucosis. Stipite albido, deorsum incrassato, subpubescente ad apicem, ad basim autem albomycelioso. Carne alba, miti. Habitat ad folia in quercetis. Novembri mense, Ann Arbor, Michigan.

Singer recorded the following data from a study of Kauffman's collection: Pileus medium-sized, infundibuliform, smooth, glabrous except at the margin, where it is strongly pubescent and involute, whitish; context white; odor unknown; taste mild in the dried material; lamellae alutaceous yellow in dried condition and about 3 mm. broad (narrow), not anastomosing, simple, deeply decurrent; lamellulae rather abruptly sinuate to emarginate, only a few sub-

sinuate-attenuate; stipe whitish, thickened downward, glabrous except at the very apex, where it is very faintly pubescent, base white-mycelioid and covered with attached leaves. Spores 4–7 × 3.2–6 μ, hyaline, rather irregular in size and shape, mostly ellipsoid, with little or no depression, with strongly amyloid isolated warts. Basidia 23–37 × 5.2–6.5 μ, four-spored. Gill trama subintermixed to almost regular, consisting of hyphae 2–9.5 μ thick.

The following description is transcribed from Kauffman's notes on the fresh specimens: Pileus up to 50–70 mm. broad, at length depressed, sometimes umbilicato-depressed, appressed-floccose, pale yellowish to buff or creamy whitish, even, not truly pliant, margin persistently incurved (narrowly); context yellowish to whitish, 4–5 mm. thick toward the stipe, tapering gradually to the margin; lamellae yellowish, more so in age, adnate to decurrent, close, moderately broad (5–6 mm. in the middle), acuminately narrowed to the stipe, edges entire; stipe moderately stout, 40–50 mm. long, 8–12 mm. thick, incrassate below, floccose-silky at junction with gills, heavy-white-mycelioid below, silky-fibrillose and glabrescent elsewhere; spores 5–6 × 4–5 μ, gill trama subinterwoven; cystidia and sterile cells none.

Habitat. — On leaves in oak woods. November.

Distribution. — Known only from the type locality.

Material studied. — A collection by C. H. Kauffman, near Ann Arbor, Michigan, November 14, 1926, type (Mich.).

Observations. — Kauffman identified the collection as *Clitocybe subhirta,* but it differs from Peck's material in the form of the pileus, the less uniform and less buffy color of the whole carpophore, and the mild taste of the dried plant as well as in the deeply decurrent lamellae. Kauffman did not give any information on the odor or the taste of the fresh specimens, and his line drawings, with his notes, indicate a pileus only slightly depressed, whereas in the specimens it is more or less infundibuliform, with an incurved margin. The change in shape was doubtless caused by the shrinking of the flesh as the carpophores dried. Since such a change did not take place in the type of *subhirtus,* it is likely that the difference in the shape of the pileus is distinctive. There is no evidence of overheating in the type of var. *Kauffmanii.* The taste should distinguish between these two very readily if the other characters noted are found to intergrade.

(*e*) *Leucopaxillus albissimus* var. **lentus** (Post apud Romell) S. & S., comb. nov.

Agaricus (*Tricholoma*) *lentus* Post apud Romell, Botan. Notiser for the year 1895 (1): 65. 1895.
Tricholoma lentum Sacc., Syll. Fung., 14: 72. 1899.

Illustration: Plate I.
Exsiccati: Lundell & Nannfeldt, Fungi Exsiccati Suecici, No. 202. 1936.

Description of forma **typicus** (*Tricholoma lentum* Rom., *l. c.*). Some of the macroscopic data are adopted from Romell.

Pileus 20–80 mm. broad, fleshy, convex, becoming plane or with a shallowly depressed disc, the margin frequently wavy, surface dry, more or less woolly fibrillose when young, appressed-fibrillose in age, white or disc faintly tinged buff in extreme age, not changing where handled, the disc becoming pale tan at times in drying; flesh white, firm, odor weak, taste mild; lamellae white, very pale cream-color in dry specimens or very pale buffy tan, adnate and even slightly sinuate (then with a decurrent tooth or with longitudinal ridges extending down the apex of the stipe), often merely decurrent or more or less irregularly decurrent; lamellulae abruptly sinuate; stipe variable in size and shape, 30–60 mm. long, 10–18 mm. thick, clavate to equal, solid, concolorous with the lamellae, the apex more or less ribbed by the decurrent lines of the lamellae, with a cottony-white mycelium holding débris to the base.

Spores $6–8.2 \times 4–5.5\ \mu$, rough with scattered strongly amyloid warts, ellipsoid or almost ovoid, with scarcely any epihilar depression, sometimes with one oil drop; basidia $29–36 \times 8–9\ \mu$, four-spored; pleurocystidia none; cheilocystidia scattered, fusoid-subulate, about $5\ \mu$ thick, acute; subhymenium ramose, thin; gill trama subregular; hyphae of the flesh with clamp connections.

Habitat. — On thick layers of decaying needles of *Picea excelsa*. Gregarious. In Washington it was found under Douglas fir and species of Abies. September-November.

Distribution. — Scandinavia and Washington (see forms 1 and 2 also).

Material studied. — Authentic material coll. and det. Romell, in Sweden (NY); Fungi Exsiccati Suecici no. 202 (LE); fresh specimens, Smith no. 17392, from Washington (Mich.).

Observations. — This variety is distinguished from most of the

forms met with in the eastern United States by its mild taste. It is much smaller than var. *paradoxus* and its form *albiformis*. Var. *barbarus*, which is not now known to occur in North America, appears to be closest to it. Two additional forms from Washington are described below.

(1) *Leucopaxillus albissimus* var. *lentus* f. **olympianus** S. & S., f. nov. Plate II

Habitu magis clitocybiformi vel constantius clitocybiformi omnibusque in partibus paululo maior est.

Pileus 30–90 mm. broad, convex with an involute, cottony margin, becoming plane or the margin uplifted slightly, surface dry and appearing matted-fibrillose under a lens, the margin sometimes more or less ribbed, dull white when young, soon creamy on the disc or in age, sometimes becoming pale tan, the margin remaining whitish or becoming chalk-white; context white, 10–12 mm. thick in the pileus at the stipe, tapered abruptly, soft and cottony, odor pungent-subfarinaceous, taste mild or slightly farinaceous in old caps; lamellae white to pale cream-color and staining yellowish brown in age, close to almost subdistant (56–62), some forked near the stipe, broad (7–10 mm.), tapered to the cap margin, with even or wavy edges, adnate but soon developing a decurrent tooth and finally quite decurrent; stipe 30–60 mm. long, 10–15 mm. thick at the apex, equal or clavate, dull white, unpolished, more or less white-tomentose around the base and with a copious white mycelium holding débris to the base in a compact mat, otherwise glabrous.

Spores 6–8.5 × 4.5–5.5 μ, hyaline, with strongly amyloid warts, 0–1 oil drop, ellipsoid to almost ovoid, lacking or with only a slight depression; basidia 28–35 × 7.5–8.3 μ, four-spored, rarely two-spored; pleurocystidia and cheilocystidia none; subhymenium ramose, about one third to one half the thickness of the hymenium; gill trama rather regular, consisting of interwoven thin hyphae (3) 4–5 (10) μ thick.

Habitat. — On needle carpets under Douglas fir. Gregarious. September.

Distribution. — Known only from the type locality, Lake Mills, Olympic Mountains, Washington, Sept. 26, 1941, A. H. Smith nos. 17257, 17333.

Observations. — This form differs from the typical form in its

stature. It has the aspect of a Clitocybe rather than that of a Tricholoma.

(2) *Leucopaxillus albissimus* var. *lentus* f. **furcatus** S. & S., f. nov.

Habitu magis clitocybiformi vel constantius clitocybiformi, lamellis furcatis.

Pileus 40–70 mm. broad, obtuse or gibbous when young, obscurely umbonate to plane in age, the margin opaque and involute at first, in age the margin spreading or slightly raised, snow-white because of a thin coating of appressed white fibrils, when wet or in age more or less glabrescent; context white, not changing when bruised but becoming more or less tawny in age, moderately thick and firm, odor none (old water-soaked specimens fragrant), taste mild; lamellae white to cream-color or becoming tawny-brown-spotted when water-soaked, narrow, short-decurrent, close to crowded, frequently forking or anastomosing, lamellulae present but not regularly arranged, abruptly rounded; stipe 30–50 mm. long, 8–12 mm. thick, solid, more or less equal or both apex and base slightly enlarged, white when young but sordid watery-buff in age, with a white mycelium holding the débris together around the base, surface glabrous to thinly appressed-fibrillose but unpolished.

Spores $6\text{–}7 \times 4\text{–}5$ μ, warty, the warts strongly amyloid and projecting 0.4–0.5 μ, depression slight or lacking, nearly ellipsoid; basidia $28\text{–}33 \times 7\text{–}7.7$ μ; pleurocystidia and cheilocystidia none; gill trama as in f. *olympianus*.

Habitat. — Under Douglas fir. Gregarious. Elevation about 3,500 feet. September.

Distribution. — Known only from the type locality in the State of Washington.

Material studied. — Fresh material from Boulder Creek Trail, Mt. Baker, Washington, coll. and det. E. B. Mains and A. H. Smith no. 16593 (Mich.).

Observations. — This form differs from f. *olympianus* and typical material of the variety in the strongly forked gills, which remind one of *Clitocybe aurantiaca*, and in the covering of the pileus, which reminds one of that of *C. dealbata*. In the field it is not readily distinguishable from a pale form of *C. aurantiaca* that is fairly common in the Olympic and Cascade Mountains.

(*f*) *Leucopaxillus albissimus* var. **barbarus** (Maire) S. & S., comb. nov.

Lepista barbara Maire, Bull. Soc. Myc. Fr., 40 (4) : 303. 1925.
Leucopaxillus barbarus (Maire) Kühner, Bull. Soc. Linn. Lyon, 5 (16) : 125. 1926.
Leucopaxillus barbarus var. *microsporus* Maire, Fungi Catalaunici. Publicacions de la Junta de Ciències Nat. Barcelona, 3 (2) : 76. 1933.

Illustration: Maire, *l. c.*, pl. 24.

Pileus 20–70 mm. in diameter, convex then plane and even a little depressed in the center, regular, then wavy and sometimes difform, with incurved and faintly pruinose margin, which later becomes expanded and glabrous, moist, subviscid, soon dry and appearing as if frozen, with adnate cuticle, glabrous, white, becoming ochraceous in old specimens; context white, very thick in the center, thin toward the margin, elastic, firm in the pileus, tough and fleshy-fibrous in the stipe; odor farinaceous and like that of *Cortinarius purpurascens;* taste mild; guaiac positive; NH_3 negative; lamellae white, dirty yellow in age, crowded, thin, separable from the context of the pileus, rather broad, very soft, arched, attenuate at both ends, deeply decurrent, not anastomosing, lamellulae more or less rounded; stipe white, somewhat villose-subsquamulose at the apex, fibroso-striate, dry, confluent with the pileus, elastic, solid, subcylindrical or slightly attenuate at the base, enlarged under the lamellae, 50–60 × 7–20 mm.; mycelium white, abundant, cobweb-like, incrusting the dead leaves.

Spore print pure white; spores 7–9 × 4–4.5 μ (in var. *microsporus* 6–7.5 × 4.5 μ), hyaline, thin-walled, warty-subechinulate, amyloid; basidia 30–35 × 6–7 μ, four-spored; cystidia none; cheilocystidia none; subhymenium ramose, thin (one half of hymenium); gill trama dense, regular, consisting of scarcely unequal elongated straight hyphae 6–8 μ in diameter.

Habitat. — Woods of *Quercus Mirbeckii* and *Q. Afares* (var. *microsporus* in woods of *Q. toza*). On eocenic sandstone. Gregarious. Autumn.

Distribution. — North Africa and probably in Spain.

Material studied. — None. The description is translated and adopted from Maire, *l. c.*

Observations. — *L. albissimus* var. *barbarus* differs from var. *subhirtus* in its mild taste and the subviscid glabrous pileus. From var.

lentus it differs in its subviscid pileus and habitat. In addition, var. *lentus* is said to have a tricholomoid appearance, which is shown in our photograph, but stature is not a reliable character in that variety and hence should not be emphasized as a difference between the two varieties in question.

(*g*) *Leucopaxillus albissimus* var. **paradoxus** (Cost. & Duf.) S. & S., comb. nov., f. **eu-paradoxus** S. & S., nom. nov.

Clitocybe paradoxa Cost. & Duf., Prem. Suppl. Nouv. Flor. Champ., p. 262. 1896.
Lepista paradoxa Maire, Bull. Soc. Myc. Fr., 40 (4) : 307. 1925.
Leucopaxillus paradoxus Bours., Bull. Soc. Myc. Fr., 41 : 391. 1925. Kühner, Contrib., p. 134. 1926.

Illustrations:
Maire, *l. c.*, pl. 23.
Patouillard, Tab. Anal., Fasc. 7, No. 618. 1889 (as *Lepista amara*).
Konrad et Maublanc, Icon. Sel. Fung., 4, pl. 301.

Pileus 40–100 (usually about 60) mm. broad, convex or with a flattened disc or convex-plane with a somewhat depressed center, color cream-white, then mostly tinted with ochraceous cream-color especially in the center, very faintly rimose-areolate, the space between the areolae being paler; dry and unpolished but glabrous and smooth, the margin involute at first and more or less pubescent, later glabrous and repand and often ribbed-crenulate; flesh white, fairly tough, firm, odor strong, recalling that of *Tricholoma sulphureum* but not exactly resembling it, usually more farinaceous (of "fresh wood" — Kühner), taste disagreeable but mild; lamellae whitish, subdistant to crowded (38–100), rather narrow, not or only rarely forked (often forked, however, at the lines or ridges extending down the apex of the stipe, where they may form a network or a zone of isolated longitudinal ribs), not anastomosing at the bases of the lamellae, separable from the context of the pileus, unequally decurrent, lamellulae abruptly rounded; stipe 30–80 mm. long, 8–25 mm. thick, equal or subbulbous, if bulbous often attenuated below the bulb, solid, white or whitish, mostly covered with small appressed whitish or pale buff squamules or wholly pubescent.

Spores pure white in mass, 5–7.5 × 3.3–4.8 μ, ellipsoid or almost ovoid, with 0–1 oil drop, with strongly amyloid warts; basidia 21–41 × 4–7.5 μ, four-spored; pleurocystidia and cheilocystidia none; subhymenium ramose, thin, gill trama subregular, consisting of

hyphae 3–5 μ thick (those toward the middle of the trama often thicker); cuticle of pileus dense, consisting of thin-walled smooth hyaline hyphae about 4 μ thick (see Kühner).

Habitat. — On needles, mostly of Picea (*P. excelsa* and *P. orientalis*) in Europe and the Caucasus and on débris of Thuja in California. Gregarious, often two, rarely more, carpophores connected, often in circles. August to November and in California also in the winter.

Material studied. — Fresh material from the locality where Kühner and Maire obtained the specimens for their descriptions cited above: Forêt de Fontainebleau, coll. and det. Singer, Sept., 1935. Dried specimens from the Caucasian Reservation, Malaya Laba Valley, coll. Vassilieva, det. Singer (LE); from Mordovski Reservation, coll. Kuznetsov, det. Singer, preserved at the Reservation; from California, coll. Silva, det. E. E. Morse (NY).

Observations. — This variety differs from var. *lentus* in the consistently larger size of all parts and in both the shape and the surface characters of the stipe.

Leucopaxillus albissimus var. *paradoxus* f. **albiformis** (Murr.), comb. nov.

Clitocybe albiformis Murr., Mycologia, 5: 211. 1913.
Clitocybe stipitata Murr., Mycologia, 5: 206. 1913.

Illustrations: Plates III–IV. For the spores see Figure 2 (p. 100).

Pileus (55) 65–150 (300) mm. broad, convex to broadly convex with an involute margin, becoming obtuse or plane, the margin finally spreading or recurved and wavy and more often ribbed than smooth, surface dry and unpolished, appearing matted-fibrillose under a lens, chalk-white when young, gradually becoming yellowish from the center outward, finally "cream buff" (R.) on the disc and "cartridge buff" (R.) toward the margin; flesh white, thick (20 mm. at the stipe in large caps), firm or becoming soft, odor faintly fragrant or pungent and reminding one somewhat of *Tricholoma sulphureum*, taste mild; lamellae pure white to "tilleul buff" (R.), crowded (100–120), many-forked near the stipe, separable from the context of the pileus, narrow to moderately broad (6–8 mm.), narrowed to the cap margin but nearly equal in width most of the distance, unequally decurrent and soon developing decurrent lines, with even

but often undulating edges, decurrent lines on stipe occasionally anastomosing, lamellulae abruptly rounded; stipe (60) 80–150 (200) mm. long, (10) 15–20 (40) mm. thick, nearly equal to decidedly ventricose in lower part, almost always tapered to a pointed base, covered by a mat of débris held together by a copious mycelium, solid, white throughout or surface cream-color to pale buff, pruinose-scurfy to pubescent above or rather evenly covered by minute innate squamules, fibrillose-scurfy or at times even lacerate-scaly in age.

Spores white in mass, 5.8–8 × 3.5–5 μ, hyaline, with strongly amyloid warts, ellipsoid, thin-walled; basidia 27–30 × 6–8 μ, four-spored; cystidia and cheilocystidia none; gill trama subregular; trama of pileus homogeneous, clamp connections present on the hyphae.

Habitat. — On needles and around old conifer stumps under conifers, very often under cedar and fir. Gregarious to subcespitose. Autumn and, in California, winter.

Distribution. — Washington, Oregon, and California.

Material studied. — Type material of *Clitocybe stipitata* Murr. from Stanford University, California (NY); type material of *Clitocybe albiformis* Murr. from Searsville Lake, California (NY). Fresh material from Trinidad, California, H. E. Parks and A. H. Smith no. 3626 (Mich.); A. H. Smith no. 9278, Oregon; 8513, 8712, and 8791, California; T. T. McCabe, Feb. 1, 1938, California, comm. E. E. Morse (Mich.); A. H. Smith no. 17391, Washington (Mich.). Dried material from Bremerton, Washington, 1932, coll. J. B. Flett, det. E. E. Morse (FH); from Seattle, Washington, coll. and det. Zeller (NY).

Observations. — This form differs from f. *eu-paradoxus* in the yellower lamellae of the dried specimens and the more consistently fusoid stipe.

KEY TO VARIETIES AND FORMS OF *L. ALBISSIMUS*

A. Taste bitter or farinaceous-bitterish (American plants)
   1. Color pure white in either fresh or dried condition (if properly prepared). In mixed forests, rarely in pure stands . . . . var. *typicus*
   2. Older or dried specimens, buff to tan at least in places
      a) Occurring only in frondose woods. Lamellae not deeply decurrent by ridges or lines. Mycelium soft, silky, copious, pure white. Pileus slightly pubescent when young . . . . var. *subhirtus*
      b) Nearly always under conifers or in mixed forests. Lamellae mostly with anastomosing lines or ridges on the apex of the stipe. Base

of stipe strigose or coarsely fibrillose with concolorous fibrils. Pileus almost glabrous .... var. *piceinus*

B. Taste mild or sometimes somewhat disagreeable
  1. In frondose woods. Pileus either decidedly infundibuliform and somewhat hairy-pubescent or subviscid when young and fresh
    a) Pileus glabrous, subviscid. In northern Africa and possibly Spain var. *barbarus*
    b) Pileus somewhat hairy pubescent, decidedly infundibuliform at least in age. Michigan .... var. *Kauffmanii*
  2. In coniferous woods. Pileus mostly only thinly fibrillose and not distinctly infundibuliform, surface perfectly dry
    a) Stipe glabrous in the midportion, 30–60 × 8–15 mm. On needle beds under conifers (Picea, Abies, and Pseudotsuga). Northern Europe and the State of Washington .... var. *lentus*
      1) Stature of a Tricholoma .... f. *typicus*
      2) Stature of a Clitocybe
        (a) Few lamellae forked .... f. *olympianus*
        (b) Many lamellae forked .... f. *furcatus*
    b) Stipe not glabrous over the midportion .... var. *paradoxus*
      1) Lamellae white or whitish in dried plants if properly prepared. Stipe subfusoid, 30–80 × 8–25 mm. Southern and eastern Europe and the Caucasus, also in California .... f. *typicus*
      2) Lamellae yellowish in dried specimens, stipe 60–200 × 15–20 (30) mm. Western United States .... f. *albiformis*

5. **Leucopaxillus nauseosodulcis** (Karst.) S. & S., comb. nov.

Clitocybe nauseosodulcis Karsten, Hedwigia, 12: 177. 1883.
Pleurotus nauseosodulcis Saccardo, Syll. Fung., 5: 448. 1887.

Illustration: Karsten, Icones Selectae Hymenomycetum Fenniae, fig. 23. 1883.
Exsiccati: Karsten, Finland Fungi.

Pileus 50–250 mm. broad, convex then plane, smooth, glabrous, the thin margin irregular and unequal, alutaceous throughout; context thick and soft, odor weak but disagreeable (very fetid in the partly dried plant), taste sweetish but nauseous; lamellae pale, linear, crowded, rather broad (10–15 mm.); stipe 40–140 mm. long, 10–50 mm. thick, solid, eccentric or rarely central, whitish, tomentose but becoming glabrous.

Spores 7–7.5 (8) × 5.3–5.5 μ, hyaline, with strongly amyloid warts, short-ellipsoid to almost ovoid; basidia 35–36 × 6–7 μ; sterigmata 4 μ long; pleurocystidia and cheilocystidia not seen; gill trama subregular, consisting of cylindric, thin (2–3 μ near the subhymenium), nonamyloid hyphae with clamp connections; no lactiferous hyphae seen; hyphae of the cuticle of the pileus very interwoven, smooth, often about 5 μ thick, septate, and nearly always with clamp connections.

Habitat. — On anthills. Connate-cespitose, rarely singly. September.

Distribution. — Finland.

Material studied. — Karsten, Finland Fungi, *Clitocybe nauseoso-dulcis* (NY).

Observations. — Karsten considered his species to be related to *Pleurotus sapidus*, a true Pleurotus, but Pilát (10) notes that it hardly belongs in that genus. Our investigations on the authentic material preserved at the New York Botanical Garden prove it to be a Leucopaxillus instead. It is close to *L. albissimus*, but is easy to distinguish by its eccentric stipe, its taste and odor, and possibly by the peculiar habitat. The description above is made up from a translation of the original description and Singer's notes based on his study of the exsiccatus.

6. **Leucopaxillus pulcherrimus** (Peck) S. & S., comb. nov.

Clitocybe pulcherrima Peck, Journ. Myc., 14: 1. 1908.

Illustration: For the spores see Figure 6 (p. 100).

Pileus 25–50 mm. broad, convex becoming umbilicate or centrally depressed, decurved on the margin, glabrous, lemon yellow; context white, yellowish under the cuticle; lamellae whitish or faintly tinged with yellow, thin, close, arcuate, decurrent; stipe 25–40 mm. long, 6–8 mm. thick, solid above, hollow toward the base, equal or slightly tapering upward, concolorous with or a little paler than the pileus.

Spores 4–5.8 × 3.5–4.5 μ, strongly amyloid, subglobose, warty; basidia 23–32 × 4–7 μ, four-spored; pleurocystidia and cheilocystidia none; gill trama consisting of interwoven, nonamyloid hyphae; cuticle of pileus compact, consisting of thin interwoven hyphae.

Habitat. — Among fallen leaves.. September-October.

Distribution. — Michigan.

Material studied. — Part of type (from near Detroit) preserved at the New York Botanical Garden and another part in the Herbarium of the University of Michigan.

Observations. — The description above is based only on Peck's account and notes on the microscopical characters obtained by us from a study of the type. Kauffman (3) is the only other author who has given a description based on fresh material. He states that the

color of the pileus is citron color to cream-color of Saccardo and that it fades. In addition, he described the pileus as slightly silky-tomentose on the disc, the margin as even, the flesh as white or sometimes tinged cream-color, the lamellae as ochraceous yellow, narrow, equally decurrent, subdistant, a few forked and the edges as entire. He described the stipe as silky-tomentose at first, then fibrillose with loose longitudinal fibrils and even. The odor and taste were given as mild. This is apparently a very beautiful species and related in no way to those indicated by Peck (*Clitocybe vernicosa, C. veneris, C. venustissimus*), but rather to *L. albissimus* and *L. laterarius*. These two are readily distinguished by their different colors.

7. **Leucopaxillus laterarius** (Peck) S. & S., comb. nov.

Agaricus (*Tricholoma*) *laterarius* Peck, Bull. Buffalo Soc. Nat. Sci., 1 (2) : 43. 1873.
Tricholoma laterarium Saccardo, Syll. Fung., 5 : 101. 1887.
Melanoleuca lateraria Murrill, North Am. Flora, 10 (1) : 10. 1914.

Illustrations:

Plate V. For the spores see Figure 1 (p. 100).
M. E. Hard, The Mushroom, Edible and Otherwise. Its Habitat and Its Time of Growth, fig. 47.
Kauffman, Agar. Mich., II, pl. 151 (as *Tricholoma acerbum*).

Pileus (40) 70–120 (200) mm. broad, when young obtuse to broadly convex with an inrolled margin, becoming broadly convex to plane, sometimes obtusely umbonate, surface dry and unpolished, under a lens appearing somewhat matted-fibrillose, in age at times becoming minutely scurfy or with spotlike patches (not true scales) around the disc, the margin frequently ribbed or grooved, entirely white or with a faint flesh-pink tinge (between white and "vinaceous buff" — R.), sometimes creamy yellowish over the disc; context white, thick and firm, unchanging, odor farinaceous and sometimes rather disagreeable, in dried individuals somewhat spicy, taste sub-astringent to very bitter; lamellae white or pale cream-color in age, narrow, crowded, with entire edges, adnate to sinuate but decurrent by lines which do not anastomose; stipe 40–110 mm. long, 6–20 mm. thick at the apex, solid, very firm, subequal or clavate and 30–40 mm. thick at the base, surface unpolished to minutely pubescent, remaining unpolished in age, white throughout, usually with a mass of white mycelium surrounding the base and penetrating through the adherent leaves.

Spores white in mass, 3.5–5.5 × 3.5–4.7 μ, globose to short-ellipsoid, most frequently subglobose, thin-walled, hyaline, very slightly rough to verrucose, the warts strongly amyloid; basidia 22–31 × 5.5–7 μ; four-spored; pleurocystidia none; cheilocystidia lacking or very scattered, 2–5.5 μ thick; pileus trama homogeneous, its hyphae bearing clamp connections.

Habitat. — In frondose woods, particularly on accumulations of leaves and débris of Quercus and Fagus. Singly to scattered. July-November.

Distribution. — Eastern part of North America from Canada to Florida and west to Michigan.

Material studied. — The type, from Worcester, New York (NYS). Fresh material from Chocorua, New Hampshire, coll. D. H. Linder and R. Singer (FH). Dried material from Ontario, Canada, Bear Island, Lake Timagami, University of Toronto Crypt. Herb. no. 76425, coll. and det. H. S. Jackson (one portion FH); from North Carolina, coll. Totten (det. as *Clitocybe albissima*) (NY); from Ball Camp Pike, Knox Co., Tennessee, coll. and det. L. R. Hesler no. 10924 (FH and Mich.); from Florida, coll. and det. Murrill (as *Tricholoma albissimum floridanum* Murr., part of type?) (FH); from Seventh Lake, Adirondack Mountains, New York, coll. H. M. Fitzpatrick, W. W. Ray, W. L. White, det. H. M. Fitzpatrick (as *Clitocybe candida*) (FH). The following collections are deposited in the University of Michigan Herbarium: L. C. C. Krieger (Kelly Herb. no. 1744), Magnetawan, Ontario, Canada; Kauffman, Ithaca, New York, July 13, 1903; Kauffman, Washtenaw County, Michigan, Oct. 12, 1904; Smith, Ann Arbor, Michigan, July 1, 1929, det. Kauffman (as *Tricholoma acerbum*); Smith, nos. 1413, 1449, and 3979 from Michigan; Stuntz and Smith no. 15165, Oakland County, Michigan, July 2, 1930.

Observations. — In Michigan Smith has observed that during certain seasons small (40–80 mm. broad) white specimens occur, whereas during other seasons one finds large fruiting bodies with cream-colored pilei 100–150 mm. broad. Regardless of whether the pileus is white, cream buff, or the characteristic pale pinkish buff, the small spores are an infallible character. *L. laterarius* is rather common in eastern and east-central North America. The name *Tricholoma acerbum*, which was applied to it by Kauffman and others who followed him, should be discarded in favor of the name

given by Peck to American material. *T. acerbum* sensu Bresadola is a typical Tricholoma, with nonamyloid spores and without clamp connections. *T. acerbum* sensu Lange may be close to Kauffman's concept of that species, but Lange has not given sufficient information to allow one to be certain of the identity. His fungus, to judge from his plate, is more highly colored than the American species, but does have the very small spores. Lange, however, did not give the iodine reactions of the spores of Tricholoma; hence, unless he has preserved his specimens, it will be impossible to determine whether his species is or is not a Leucopaxillus.

8. *Leucopaxillus rhodoleucus* (Romell) Kühner, Bull. Soc. Linn. Lyon, 5 (16) : 125. 1926

Agaricus (*Clitocybe*) *rhodoleucus* Romell, Botan. Notiser for the year 1895 : 66. 1895.
Clitocybe rhodoleuca Saccardo, Syll. Fung., 14 : 74. 1899.
Lepista rhodoleuca Maire, Bull. Soc. Myc. Fr., 40 (4) : 305. 1925.
Illustrations: Maire, *l. c.*, pl. 20, figs. 2–7.

(*a*) *Description of the Swedish plant* (*from the original by Romell*). — Pileus white in dry weather, pinkish in wet weather, becoming glabrous, fleshy, convex or at last almost plane, very rarely somewhat concave, 20–80 mm. in diameter. Context white, odor weak, taste mild. Lamellae pink or incarnate-pale, in wet weather more intensely colored, almost crowded, narrow (1–5 mm.), some forked, decurrent. Stipe concolorous with the pileus, conic or nearly cylindric from a thickened base, 20–40 × 5–20 mm.

Spores white in mass, 6–9 × 5–6.5 μ, hyaline, slightly rough, obovate; basidia 30–45 × 8–9 μ, four-spored; cystidia none.

Habitat. — On needles under *Picea excelsa*. Gregarious to cespitose. August–November.

(*b*) *Description given by R. Maire.* — Pileus snow-white, then more or less marked with droplike spots or marbled, usually concentrically, by purplish-gray or yellowish-gray hygrophanous spots, with separable moist subviscid cuticle, later dry, glabrous, fleshy, convex then plane and slightly depressed at the center, often more or less wavy, 40–80 mm. in diameter. Context white with a pink reflection in the pileus, purplish gray and hygrophanous next to the lamellae, thick, firm in the pileus, fibrous-fleshy in the stipe, taste mild, rather sweet, odor faint, guaiac negative. Lamellae

pinkish white, especially in the space between the lamellae, becoming whitish, anastomosing at times, crowded, not separable from the context of the pileus, thin, narrow (3–4 mm.), arcuate, attenuate at both ends, deeply decurrent, lamellulae attenuated at inner extremity; stipe white, opaque, glabrous or somewhat furfuraceous-fibrillose at the apex, dry, solid, subcylindric or somewhat enlarged toward the base, confluent with the pileus, 30–40 × 12–23 mm.

Spores pure white in mass, 7–9 × 4.5–5.5 μ, hyaline, warty, amyloid, thin-walled, short ellipsoid-obovate, with one or several droplets; basidia cylindric-subclavate 40–50 × 8–9 μ, four-spored; pleurocystidia none; cheilocystidia none; subhymenium ramose, rather thick (three fourths the thickness of the hymenium); gill trama regular, compact, consisting of rather short cells 6–10 μ thick.

Habitat. — On needles of *Cedrus atlantica.* Gregarious, sometimes two carpophores connate. Autumn.

Distribution. — Sweden, France, and North Africa, according to Maire.

Observations. — We have not examined material of this species, which we include on the basis of R. Maire's account, summarized above. The original description and that of Maire are given separately because of some disagreement among European authors over the identity of Romell's species. Bresadola in his *Iconographia,* Vol. 3, pl. 117, stated that he had compared the original material of *Clitocybe rhodoleuca* Romell with his *Tricholoma panaeolum* and found it to be a form of the latter with decurrent lamellae. We do not accept Bresadola's statement as final, however, because it is now known that his *T. panaeolum* is a mixture of two species, *Rhodopaxillus caespitosus* and *R. nimbatus,* both of which have sordid pinkish spore prints. Since Romell was a very accurate observer so far as the exact colors of spore prints were concerned, we do not believe this species had spores that were dirty pinkish in mass, and we therefore accept Maire's account. *L. rhodoleucus* is probably very difficult to distinguish from species of Rhodopaxillus of the section Panaeoli if (like Bresadola) one does not know one of them to begin with and if one does not use the iodine reaction of the spores, a character also not employed by Bresadola. *L. rhodoleucus* must resemble *Clitopilus prunulus* so far as its macroscopical appearance is concerned. It differs from other Eu-Leucopaxilli in having attenuated lamellulae, hygrophanous spots, and pinkish lamellae in-

separable from the hymenophore as well as a comparatively thick subhymenium.

9. *Leucopaxillus tricolor* (Peck) Kühner, Contrib., p. 135. 1926.

Tricholoma tricolor Peck, Ann. Rep. New York State Mus., 41 : 60. 1888.
Melanoleuca tricolor Murrill, North Am. Flora, 10 (1) : 17. 1914.
Tricholoma pseudoacerbum Cost. & Duf., Prem. Suppl. Nouv. Flor. Champ., p. 259. 1896.
Leucopaxillus pseudoacerbus Boursier, Bull. Soc. Myc. Fr., 41 : 392. 1925.
Lepista pseudoacerba Konrad & Maublanc, Icon. Sel. Fung., 6 : 350. 1937.

Illustrations:
Plate VI. For the spores see Figure 4 (p. 100).
Kauffman, Agar. Mich., II, pl. 155. 1918 (as *Clitocybe maxima*).

Description of the American type. — Pileus 90–300 mm. broad, convex to plane or with a broad low obtuse umbo, the margin strongly inrolled, sometimes slightly depressed in the center (scarcely subinfundibuliform in age — Kauff.) surface dry, unpolished and matted-fibrillose (more or less like felt), opaque at all stages, margin furrowed or grooved, color pale alutaceous inclining to russet (see Peck) ("pinkish buff" at first, soon darker and dull tan over the disc — Smith), becoming darker as it ages or dries ("vinaceous," "deep vinaceous," "dark vinaceous," "hydrangea red," or "mineral red" in dried plants — Singer); flesh very thick and firm but becoming thinner and flabby in very old individuals, white or whitish, odor and taste pungent to farinaceous, rather strong and disagreeable (taste mild — Kauff.; odor like that of *Agaricus campestris* — Ellis); lamellae close to crowded, readily separable from the pileus, "marguerite yellow" (pale clear yellow) in fresh young plants (whitish — Kauff.), becoming darker yellow in age, and when dried becoming dark reddish or purplish (the color very distinctive), narrow to broad, broadest in old specimens; stipe 40–60 (100) mm. long, 10–30 mm. thick at apex, sometimes 40 mm. at the base, tapering or equal upward from a thickened or abruptly bulbous base, solid and fleshy, white within, surface whitish and unpolished or with a thin cottony-tomentose covering (often stained ferruginous . . . the bulb at length the color of the pileus — Kauff.).

Spores white in mass, 6–8 × 4–5.5 μ, hyaline, shortly ellipsoid, with a slight depression, thin-walled, oil drop medium-sized, surface covered with distinct isolated strongly amyloid warts; basidia 26.5–

30×6.7–$7\ (9)\ \mu$, four-spored; pleurocystidia none; cheilocystidia usually present but rare, scattered among the basidia; subhymenium thin and ramose; gill trama subregular; the whole hymenium covered with a lilac amorphous granular mass in dried specimens.

Habitat. — In frondose woods, usually under Quercus. Singly, scattered, gregarious, or subcespitose. July-October.

Distribution. — Eastern United States.

Material studied. — The type from Selkirk, New York (NYS). Authentic material from Round Lake and South Ballston, New York (typical) (NY). Fresh material from Oakland County, Michigan, coll. and det. Smith, nos. 6897, 6954, 7052, 7269, 7304, 10993, 15464 (Mich.). Dried specimens from New Jersey collected by Ellis, who considered it representative of a new species (FH); from Auburn, Alabama, coll. C. F. Baker (FH); Kauffman's Michigan collections, numbering four, determined as *Clitocybe maxima* (Mich.).

Observations. — This species has the appearance of a large Tricholoma, and is unmistakable in the dried condition. Kauffman in his *Agaricaceae of Michigan*, p. 721, described it in detail under the name *Clitocybe maxima* Fr. and then merely quoted Peck's description for *Tricholoma tricolor*. His description and comments, so far as they apply to the material he studied, are excellent, but his remarks about the relationships of the species should be disregarded. From the studies of Kauffman and of Smith on Michigan specimens it is evident that the color of the gills is a somewhat variable character, and that the differences noted in the existing descriptions are best interpreted as various stages in the change of color that takes place as the fruiting bodies mature and age. Hence the degree of yellowness of the gills of a particular collection is of no significance taxonomically. The taste also appears to be variable. Smith noted it as given above (disagreeable). Singer found the taste of dried specimens slightly bitter. The taste of European and also Kauffman's specimens has been described as mild. Consequently it does not seem possible to distinguish European from American specimens on the basis of either character. In order to enable anyone to compare his collections with European as well as American descriptions we give the following translation from Kühner (5).

Pileus light buff, light flesh-colored-alutaceous in the center with paler cream-colored to pale sulphur-cream-color at the tomentose margin, surface punctate or like a cobweb, sometimes areolate

in the center, strongly convex with more or less ribbed margin which expands only in age, 130–160 mm. in diameter. Lamellae distinctly yellow sulphur-cream-color, crowded (120 ±, 5 tiers of lamellulae), nondecurrent but also not distinctly sinuate. Spore print white. Spores 7.5 × 4.5–5 μ, warty, amyloid, ellipsoid. Basidia 48 × 9–10 μ, four-spored. Hyphae of the rather regular dense trama 6–8 μ in diameter. Subhymenium ramose, hardly distinct from the trama. Stipe white or cream-color, the base sometimes sulphur-colored; solid, 28–36 mm. thick, thickened downward into a sometimes marginate bulb, 40 × 20 mm. Context white, thick and compact; odor not very agreeable, virose, herbaceous, or of fresh wood (the same comparison was used by Kühner for the odor of *L. albissimus* var. *paradoxus*). Taste sweetish, somewhat like that of sugar. Hyphae very interwoven, 6–10 μ broad, with clamp connections.

Habitat. — In woods (under frondose trees in September, according to Singer).

Distribution. — France.

Material studied. — Fresh specimens from Forêt de Fontainebleau, France, coll. and det. Singer.

Observations. — Singer's specimens were from the same locality from which Kühner obtained his, and were found to be identical with Kühner's in all respects. These European collections differ from American specimens in the more pronounced yellow color of the margin of the pileus and the stipe, possibly in odor, although this character is difficult to compare, and in the sweetish taste, a character of doubtful value in this instance. Boursier published a second description, which differs from the one above in a few points: pileus smooth, sometimes subtomentose, up to 200 mm. broad, pale brown ("café au lait"). Lamellae lemon yellow becoming dark violet in the herbarium, rather thick, almost free. Spores 8 × 5.5 μ. Basidia 27 × 8 μ. Subhymenium broad. Trama very broad, almost interwoven. Cuticle of thin-appressed fibrils. Stipe white, smooth, 60 × 30 mm. Context mild. In frondose woods in the grass. July-September. S. Buchet and H. Colin (2) published an interesting study on *Tricholoma pseudoacerbum* as early as 1913. They showed that the pigment of this species colors alcohol and ether a gooseberry pink, the etheric solution showing a blue fluorescence. In concentrating the solutions they obtained finally a dark brown resinaceous product. *T. acerbum* gave a very different reaction.

10. **Leucopaxillus brasiliensis** (Rick) S. & S., comb. nov.

Tricholoma brasiliense Rick, Brotéria, 6 : 72. 1907.

Illustrations: Rick, *l. c.*, pl. 9, fig. 7 (photographs).

Pileus 40 mm. in diameter, slightly depressed when expanded, submembranaceous at the involute margin, varnished-glabrous, dark violet, ashy green around the margin; flesh fuliginous, reddening, firm, odor farinaceous; lamellae bright yellow orange, crowded, narrow, unequal, forked toward the margin, subsinuate with a decurrent tooth, becoming dark vinaceous in dried condition; stipe 50 mm. long, 10 mm. thick, fleshy, solid, slightly thickened into the pileus, fuliginous-chestnut, gray-powdery toward the pileus, greenish tomentose from the mycelium toward the base, reddening in drying.

Spore print white ("sporis albis" — Rick); spores 5×3.2-4 μ, hyaline, shortly ellipsoid to globose, without hilar depression, warty, strongly amyloid; basidia 20–27×5–7 μ; cheilocystidia rather numerous in places (but an abundant dark vinaceous incrustation hindered exact observation, and it cannot be stated to what extent the edge is heteromorphous); gill trama subregular, consisting of interwoven rather narrow hyphae; hyphae of the flesh of the pileus with clamp connections.

Habitat. — In woods on the ground (among leaves).

Distribution. — Brazil.

Material studied. — Authentic material (part of type?) in the Patouillard Herbarium (FH).

Observations. — *L. brasiliensis* is related to *L. tricolor* by the shape and color of the lamellae in the fresh and dried condition, but differs in its smaller size, the color of the living fungus, and the smaller spores. The description above is made up from Rick's original account and our notes on the dried specimens.

11. *Leucopaxillus amarus* (A. & S.) Kühner, Ann. Soc. Linn. Lyon, 73 : 84. 1927.

Agaricus rivulosus ββ *amarus* Albertini & Schweinitz, Consp. Fung. Lusat. p. 185. 1805.
Agaricus amarus Fries, Syst. Myc., 1 : 87. 1821.
Clitocybe amara Quélet, Champ. Jura et Vosges, 1 : 234. 1872.
Omphalia amara Quélet, Enchir. Fung., p. 21. 1886.
Gyrophila amara Quélet, Flore Myc., p. 283. 1888.
Tricholoma amarum Rea, Brit. Bas., p. 221. 1922.

Lepista amara R. Maire *in litt.* apud Konrad et Maublanc, Icon. Sel. Fung., 4, pl. 300.
Clitocybe gentianea Quélet, Champ. Jura et Vosges, 2: 341. 1873.
Omphalia amara var. *gentianea* Quélet, Enchir. Fung., p. 21. 1886.
Agaricus vulpeculus Kalchbrenner apud Fries, Hymen. Eur., p. 83. 1874. Romell, Botan. Notiser for the year 1895: 67. 1895.
Clitocybe vulpecula Saccardo, Syll. Fung., 5: 149. 1887.
Agaricus conspicuus Lasch, Linnaea, 4: 522. 1829.
Agaricus miculatus Secr., Mycogr. Suisse, 2: 163. 1833.
Melanoleuca bicolor Murrill, Mycologia, 5: 215. 1913.
Tricholoma bicolor Murrill, Mycologia, 5: 223. 1913.
Melanoleuca roseibrunnea Murrill, Mycologia, 5: 220. 1913.
Tricholoma roseibrunneum Murrill, Mycologia, 5: 223. 1913.

Illustrations:

For the spores see Figure 5 and for the hyphae of the cuticle see Figure 7 (both figures on page 100).
Barla, Champ. Alp. Mar., pl. 50, figs. 1–9.
Cooke, Illus., pl. 132A (134A).
Lanzi, Fung. Roma, pl. 131, fig. 1.
Quélet, Champ. Jura et Vosges, 2, pl. 1, fig. 5.
Kalchbrenner, Icon. Sel. Hymenomycetum Hungariae, Fasc. 4, pl. 39, fig. 2.
Bresadola, Icon. Myc., 3, pl. 138.
Konrad et Maublanc, Icon. Sel. Fung., pl. 300.
Kühner, Bull. Soc. Myc. Fr., Atlas, pl. 24. (Supplement to Tome 44. 1928) (very good).
Lange, Flora Agar. Danica, 1, pl. 24, fig. D (very good).
Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 8, pl. 8 (photograph).
(The figures of Patouillard, Eloffe, and Britzelmayr are either wrong or poorly executed.)

In the following treatment we have divided the species into five forms, which are keyed out on pages 130 and 131.

F. *typicus*. Plate VII.

Pileus 40–80–120 (150) mm. broad, convex or very rarely obtusely umbonate, eventually more or less flattened or the disc depressed, the margin involute and sulcate at first, spreading or wavy and grooved in age, surface dry and subtomentose at first, sometimes becoming more or less glabrous, sometimes more or less subsquamulose, in age at times verruculose-areolate to subrimose, color "liver brown," "chocolate," or "Verona brown" (R.) (deep reddish brown) when young, becoming paler reddish brown at maturity or in age (between "chestnut" and "mahogany red," "tawny," or "ochraceous tawny" — R.), frequently with a much paler margin ("tilleul buff"— R.), dried specimens often between "russet" and "fawn color" (R.); context white, rather thick and firm, odor peculiar,

either strong or very faint and resembling that of *Tricholoma sulphureum* but more farinaceous; taste bitter; lamellae white, finally cream-white and then at times with ferruginous spots, narrow (3–8 mm.), close (85–110), adnate and more or less sinuate but frequently with prolonged ribs extending down the apex of the stipe, separable from the context of the pileus; stipe 40–60 mm. long, 8–45 mm. thick, equal to bulbous, solid or becoming hollowed, pure white or the base becoming sordid-brownish in age where touched, apex faintly pruinose, sometimes minutely pubescent over all.

Spore print pure white; spores 4.3–6 × 3.7–5 μ, subglobose, with little or no depression, with distinct isolated strongly amyloid warts, thin-walled, contents with one oil drop; basidia 27–33 × 6–7.5 μ, four-spored, sometimes with a few two-spored individuals intermixed; pleurocystidia none; cheilocystidia very abundant, with only scattered basidia among them, variable in shape, fusoid, clavate-cylindric or bottle-shaped, never thickened at the base, sometimes forked or variously branched, 25–38 × 2–6.5 μ; subhymenium ramose, thin; trama subregular, the hyphae 1–3 μ thick, progressively more interwoven toward the midportion of the gills and also toward the flesh of the pileus; hyphae of the flesh of the pileus with clamp connections; hyphae of the cuticle reddish brown inside from a dissolved pigment and, in addition, the walls covered by an abundant rufous-brown pigment incrusting the walls in the form of warts or rings or irregular plates. (The hyphae are thin-walled or part of them have moderately thickened walls. The cuticle is very dense.)

Habitat. — Mostly in coniferous woods (Pinus, Abies, Pseudotsuga, Larix), in southern regions also under species of Quercus. Mostly gregarious. July to November or occasionally in January.

Distribution. — Europe, Caucasus, North Africa, United States (California, Idaho, Washington, and Wyoming). If the other forms are included the distribution is extended to Colorado and also South Africa.

Material studied. — Fresh specimens from: the Nakra Valley, Svanetia, Central Caucasus, coll. and det. Singer (Herb. Naturhist. Mus. Vienna); Idaho, Smith no. 15870, and Washington no. 3178 (Mich.). Dried specimens from: Sweden, coll. and det. L. Romell (NY), California (in oak woods) det. Murrill as "*Trich. bicolor*, not typical" (NY); California, coll. Copeland, det. Morse and Mentzer as *Melanoleuca roseibrunnea* (Morse, Fungi of the Pacific Coast no.

100) (FH); California, coll. Copeland, Sept. 18, 1936 (Mich.); Wyoming, coll. Kauffman and Kanouse, det. Kauff. (Mich.).

The typical form could be further divided into a small and a large race: the first with the pileus usually less than 80 mm., the stipe narrower than 14 mm., odor constantly strong; the second with the cap usually over 80 mm. at maturity, and the base of the stipe over 14 mm. if bulbous. The latter is sometimes odorless. The specimens of Fries, Lange, and Romell belong to the smaller race. Singer's Caucasian material, Smith's Idaho collection, and certain of Murrill's and Morse's collections from the Pacific coast belong to the larger race. For those who insist on some designation for these units we suggest the names *L. amarus* f. *typicus* sf. *minor* and sf. *major*.

F. **vulpeculus** (Kalchb.) S. & S., comb. nov.

F. *vulpeculus* differs only slightly from f. *typicus* sf. *major*. It can be distinguished by its mild taste and, according to Kühner's description (his plate and description belong here), by the cheilocystidia, which are enlarged (up to 11 μ at the base). We doubt, however, whether there is really a constant difference in the shape of those organs. F. *vulpeculus* is met with chiefly in larch forests in the mountains (the Alps and the Carpathian Mountains). Romell, however, seems to have observed the same form in spruce woods.

F. **roseibrunneus** (Murr.) S. & S., comb. nov. Plate VIII

Pileus 30–140 mm. broad, broadly convex but often irregular from crowding, rarely somewhat gibbous when young, later nearly plane and the margin inrolled, surface dry and unpolished (plush-like) when young, appearing fibrillose under a lens, somewhat cottony-tomentose along the margin, in age expanded and somewhat scurfy at times, sometimes irregularly rimose and sometimes breaking up into fine scales over all except the disc, the margin spreading and ribbed or almost smooth, color dark to pale reddish brown on the disc, buff to alutaceous along the margin ("pecan brown," "russet," or "Mars brown" on disc, toward the margin "avellaneous," "wood brown," or "pinkish buff" — R.), in dry weather the color sometimes duller owing to a hoary coating, or mottled with brownish circular spots; context white, unchanging when bruised, firm and hard in the stipe, thick and tapering evenly but sharply toward the margin of

the pileus, odor faintly farinaceous to strongly rancid-farinaceous, taste bitterish to somewhat farinaceous, strong at times; lamellae milk-white to nearly pure white, not staining readily when bruised but sometimes slightly sordid in age, narrow to moderately broad (3–10 mm.), close to crowded (82–120 mm.), thin, 2–4 tiers of short individuals, edges even or slightly eroded, adnate or narrowly adnexed, frequently developing a decurrent tooth; lamellulae abruptly rounded to emarginate; stipe white, rarely buff in age, solid but frequently becoming hollow, unpolished to subtomentose or almost scabrous, somewhat glabrescent in age, base surrounded by a mat of fine white mycelial or rhizomorph-like fibrils that hold the débris together, clavate or with an enlarged bulbous base, later often becoming equal, 20–100 × 9–50 mm.

Spores white in mass, 5–7 × (3.5) 4–5 μ, hyaline, with strongly amyloid warts and little or no depression, short-ellipsoid to subglobose; basidia 31–38 × 6–8.3 μ, four-spored; pleurocystidia none; cheilocystidia cylindric, subfusoid or fusoid, some forked, rarely clavate, more frequently flask-shaped, thin-walled, hyaline, smooth, 20–45 × 2–5.5 μ, mostly 26–28 × 3.3–3.5 μ (if flask-shaped or subulate, base up to 5.5 μ, apex about 2 μ in diameter), often wavy and flexuous; subhymenium ramose, thin; gill trama subregular, dense, consisting of interwoven hyphae about 2.5 μ thick or larger in the central portion; flesh of pileus evenly filamentose, the hyphae with clamp connections; hyphae of the cuticle distinctly colored by a reddish-brown dissolved intracellular pigment, with rather distinct but rare incrustations of a reddish-brown to dark-brown (in some places hyaline) intercellular pigment that forms but faint low markings on the thin or rather thin walls, the hyphae (2) 5 (8) μ thick, the cuticle very dense.

Habitat. — In coniferous woods on needles (Abies, Pseudotsuga, Thuja, Picea) and especially in places where *Alnus rubra* is also present, in pure stands of which it often occurs in great quantities. Under oak it is met with more rarely. Gregarious to cespitose and often in arcs or rings. July-December.

Distribution. — Western part of North America: Washington, Oregon, California, Idaho, Wyoming. Possibly also in Europe and Africa.

Material studied. — Type material of *Melanoleuca roseibrunnea* from Seattle, Washington (NY). Numerous fresh collections of A. H. Smith, nos. 2486, 2557, 2569, 3150, 3308, 3877, 7803, 8067,

8201, 9277, 14814, 17024, 17358, 17404, 17561, 17932 (Mich.). Kauffman's material from Wyoming, Sept. 10, 1923, and from Oregon (Takilma and Mt. Hood) (Mich.), Epling no. 146, det. as *Tricholoma acerbum* (Mich.). One collection from Calistoga, California, coll. Curtis Wright, det. E. E. Morse (FH).

Observations. — This is the most frequent form in America. Like f. *typicus*, it can be divided into a large robust and a smaller slender subform, sf. *majusculus* and sf. *subminutus*.

F. **bicolor** (Murr.) S. & S., comb. nov.

Distinguished from the preceding form in having none or only a very little incrusting pigment on the hyphal walls, and very little intracellular pigment. The pileus is avellaneous with a pink tint. The width of the pileus is 60–120 mm. (according to Murrill). The cuticle of the pileus is dense, consisting of interwoven nonincrusted hyphae 2.5–8 μ (mostly 4–6 μ) thick. Spores 5–6.5 (7.5) $\times$ 4–5 μ, hyaline, short-ellipsoid to subglobose, thin-walled, without a depression, with 0–1 oil drop, with strongly amyloid warts. Basidia 26–40 $\times$ 6–9 μ, four-spored. Sterigmata 3.5 μ long. Pleurocystidia none. Cheilocystidia 20–35 $\times$ 2–5 μ, numerous but scattered between fertile basidia, cylindric, rarely clavate. Gill trama subregular, browner than the basidia in iodine but not amyloid, compact. Stipe 50–60 $\times$ 10 mm. $\pm$ (according to Murrill). In a dense fir forest with few old oak trees, 400 to 1000 feet elevation; also on needles (trees and elevation not determined).

This form was found in the same area as the preceding, but possibly in drier situations. It is known from Washington and California. Murrill stressed the white color of the lamellae in dried material as a distinguishing character. A great deal seems to depend, however, on how the specimens were prepared, and we doubt whether this distinction is a good one. We saw two collections, the type with whitish lamellae (NY) and one with yellowish-buff lamellae, from Pike's National Forest, Colorado (NY), which had been determined as *Clitocybe piceina.*

F. **alboalutaceus** (F. H. Møller apud Lange as Tricholoma) S. & S., comb. nov.

F. *alboalutaceus* has been found in Denmark and is said to be white (in age somewhat alutaceous). We have not studied the ma-

terial. Since F. H. Møller was the collector of Lange's material of *L. amarus* f. *typicus* he must have known this species, and therefore we are inclined to believe that var. *alboalutaceus* is nothing more than a very pale form of *L. amarus*.

Var. *gracilis* Kalchbrenner (as Agaricus) in de Thümen, Mycotheca Universalis, no. 702

This plant was collected in Somerset East near the Cape of Good Hope in South Africa on leaves (not needles) by MacOwan and Tuck. Since the edges of the lamellae are decidedly agglutinated it is rather difficult to distinguish cheilocystidia on the specimens examined (FH). The general impression is that of a slender *L. amarus*, and the characters all conform with this identification. Since the hyphae of the pileus cuticle are smooth and not incrusted (in either NH_3 or water) and are 2–5 (9) μ thick, var. *gracilis* comes nearest to f. *bicolor*. The spores were found to be warty and strongly amyloid, with only a slight depression, short-ellipsoid, 4–5.2 × 3–4 μ. The basidia are 21.5–27.5 × 5.5 μ. The gill trama is subregular. At least a few cheilocystidia are present, and the color of the cap is more or less as in *L. amarus* f. *roseibrunneus* or f. *bicolor*. The pileus measures about 40 mm.; the stipe, about 50 × 4 mm., but is thicker at the base. The lamellae are narrow and crowded. Since we do not believe that Kalchbrenner's variety deserves the same rank as the varieties of *L. albissimus*, we propose the name *L. amarus* f. **gracilis** (Kalch.) S. & S., comb. nov.

KEY TO FORMS AND SUBFORMS OF *L. AMARUS*

A. Well-pigmented forms (i.e. either incrusting intercellular pigment or dissolved intracellular pigment or both abundant)
- 1. Incrusting pigment very distinct and abundant. Color of pileus dark (see description)
  - a) Context with a bitter taste .... f. *typicus*
    - (1) Pileus smaller than 80 mm.; stipe narrower than 14 mm. sf. *minor*
    - (2) Pileus frequently or always larger than 80 mm. and base of stipe thicker than 14 mm. when it is bulbous .... sf. *major*
  - b) Context mild .... f. *vulpeculus*
- 2. Incrusting pigment rather scarce but rather distinct. Color of the pileus generally dull (see description) and produced by a dissolved intracellular portion of the pigment .... f. *roseibrunneus*
  - a) Pileus smaller than 80 mm.; stipe narrower than 14 mm. sf. *subminutus*
  - b) Pileus frequently or always larger than 80 mm. and base thicker than 14 mm. when bulbous .... sf. *majusculus*

B. Faintly or almost nonpigmented forms. Most of all hyphae of cuticle seem to be hyaline in an ammonia medium under high magnification; incrusting pigment practically none
 1. On needles of conifers. Stipe about 10 mm. thick or thicker. Occurring in Northern Hemisphere
  a) Albino form, found in Europe .... f. *alboalutaceus*
  b) Colored form, found in the western part of North America f. *bicolor*
 2. On leaves of deciduous trees. Stipe thinner than indicated above. From Southern Hemisphere .... f. *gracilis*

12. Leucopaxillus gracillimus S. & S., sp. nov.

Pileo sanguineo, glabro, subapplanato, umbonato, tenui, 35–50 mm. lato. Hyphis cuticulae haud incrustatis pigmento. Lamellis pallidis, confertissimis, angustissimis, decurrentibus. Sporis 3–5.5 × 2.2–4 μ, hyalinis, subglobosis, verrucosis, amyloideis. Stipite albo, subaequali, glabro, gracili, 45–55 × 2 mm. Carne alba, tenui. Habitat in terra, São Leopoldo, Rio Grande do Sul, Brasilia.

Pileus 20–50 mm. broad, almost flat and often umbonate, the margin incurved, glabrous, color blood red when fresh, reddish brown (almost the color of *L. amarus* f. *typicus*) when old, rather uniformly colored over all when dried; flesh white, thin in pileus and stipe, odor and taste unknown; lamellae very pale buff, probably white in fresh condition, extremely close and very narrow (reminding one of *Lentinus crinitus*), decurrent; stipe evidently white in fresh condition, nearly equal or ventricose in the lower half, 25–55 × 2–5 mm. in the dried condition, with a white mycelium at the base.

Spores 3–5.5 × 2.2–4 μ, mostly 4.7 × 3.8 μ, hyaline, short-ellipsoid to globose, without a hilar depression, warty, strongly amyloid; basidia 23–24 × 5.5–6.5 μ, four-spored; cheilocystidia 21–25 × 1.7–7 μ, filamentose, flexuous, frequently more or less thickened at the base, abundant and rendering large areas along the gill edges heteromorphous; pleurocystidia none; gill trama rather regular, no lactifers seen; hyphae in flesh of pileus with clamp connections.

Habitat. — On the ground.

Distribution. — Brazil, Province Rio Grande do Sul.

Material studied. — Dried specimens from São Leopoldo, coll. and det. (as *Clitocybe paropsis*), in 1930, Steffen, comm. Rick (FH); dried material from São Leopoldo, coll., det., and comm. Rick (1931) (FH); São Canisio do Porto Novo, Sta. Catharina, coll. Rick, 1928 (FH).

Observations. — This species seems to be rather near *L. amarus* f. *gracilis*, but when compared with it is obviously distinct because of its blood-red pileus, more slender stature, closer and narrower lamellae. The Brazilian species has nothing in common with *Clitocybe paropsis* of Europe and therefore must be described as new.

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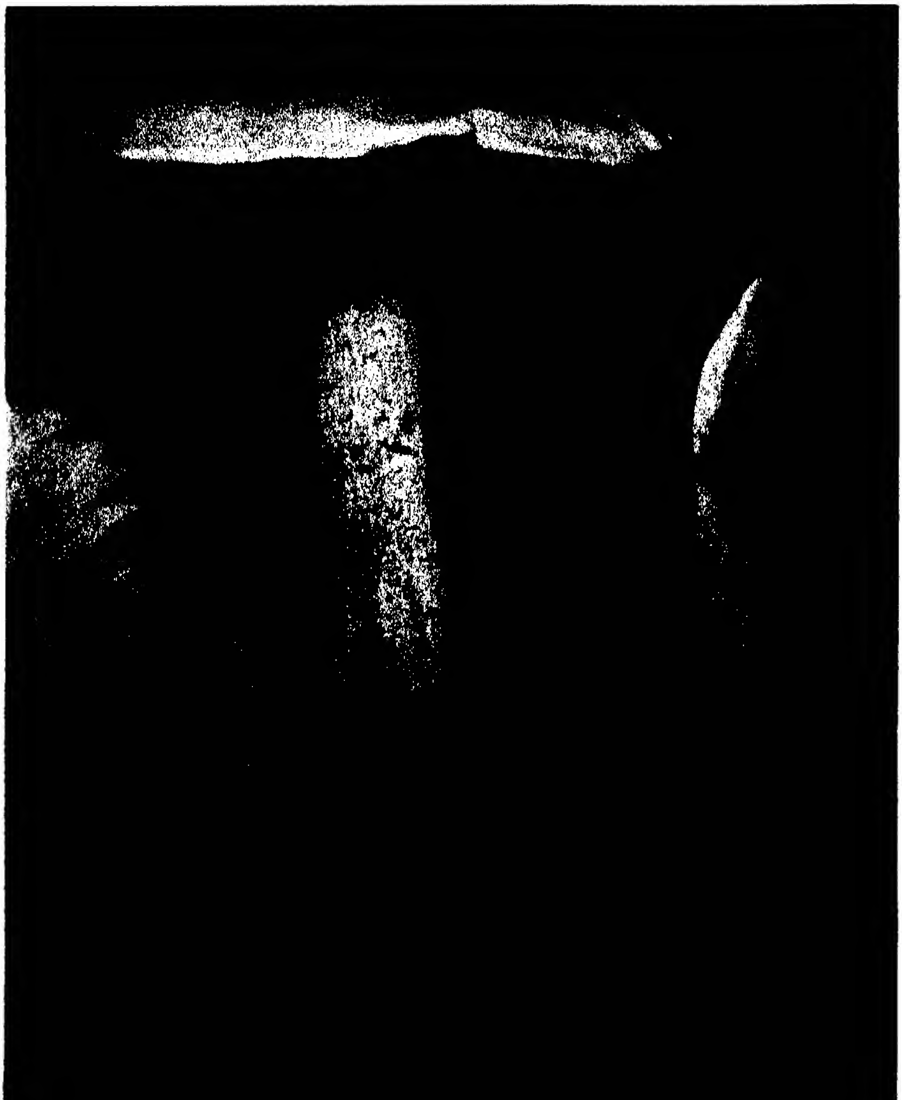
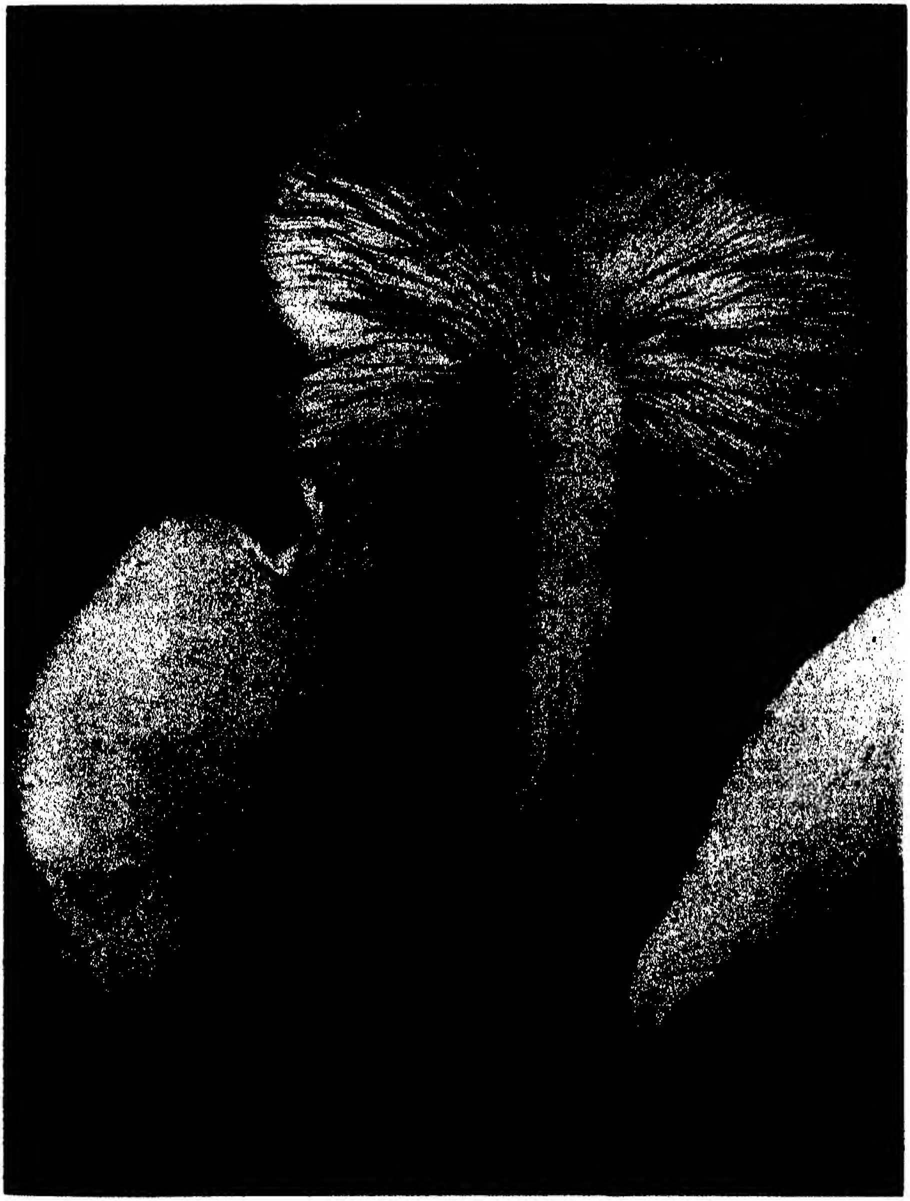
Leuco paxillus albissimus var. *lentus* f. *typicus* (Rom.) S. & S. × 1

Leucopaxillus albissimus var. *lentus* f. *olympianus* S. & S. × 1

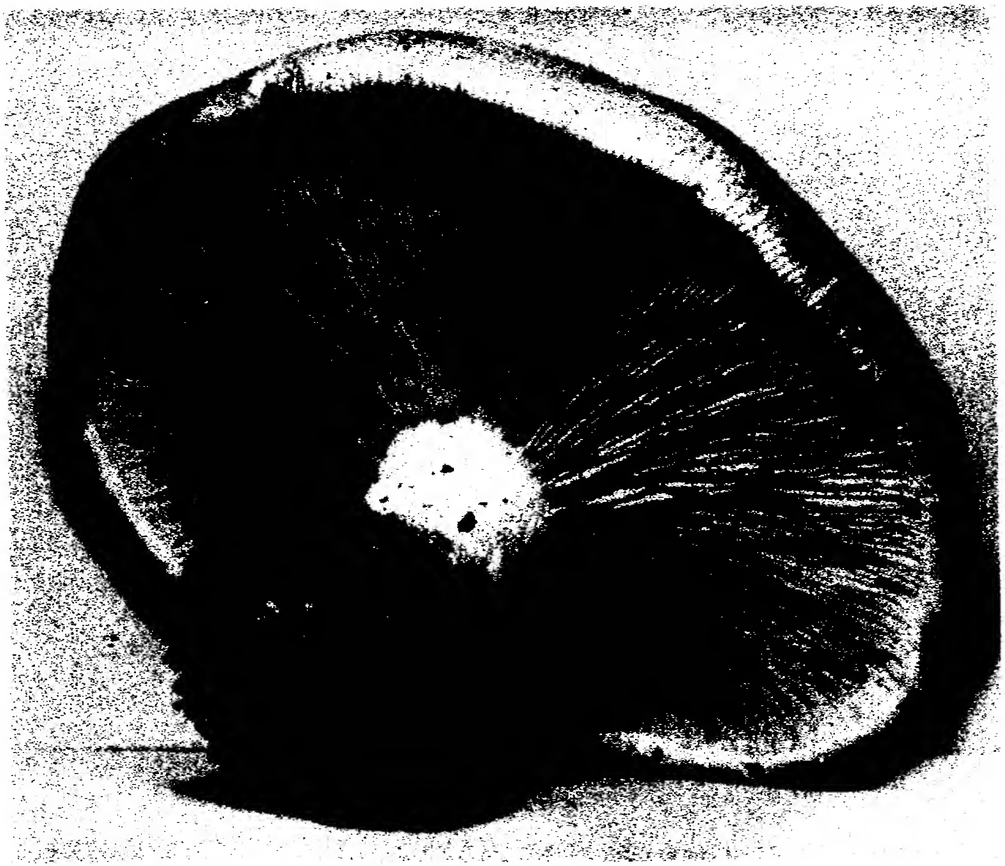


Leucopaxillus albissimus var. *paradoxus* f. *albiformis* (Murr.) S. & S. × 1

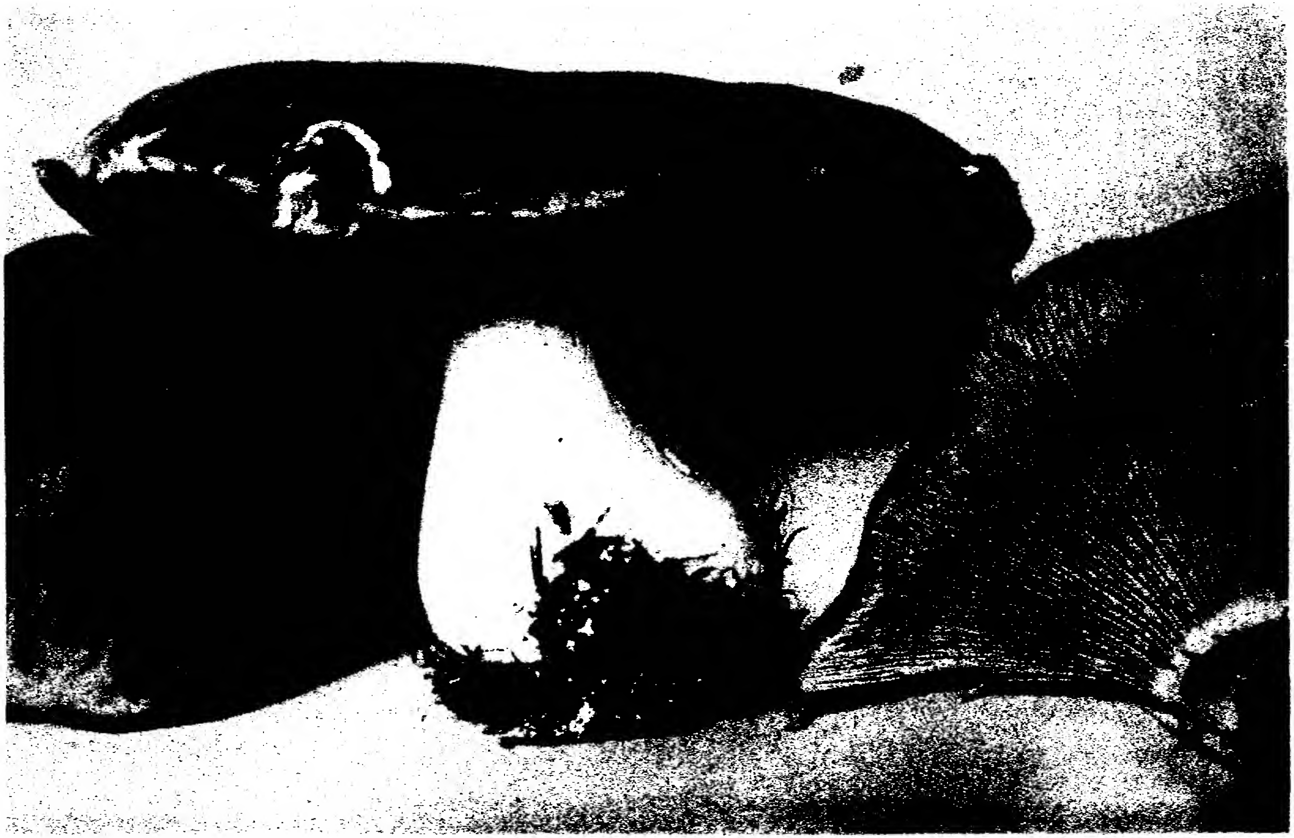


Leucopaxillus albissimus var. *paradoxus* f. *albiformis* (Murr.) S. & S. × ½

Leucopaxillus laterarius (Peck) S. & S. × 1



Leucopaxillus tricolor (Peck) Kühner. × 1



Leucopaxillus amarus f. *typicus* sf. *major* S. &. S × 1

Leucopaxillus amarus f. *roseibrunneus* sf. *subminutus* S. & S. × 1

DIFFERENCES IN MEIOTIC COILING BETWEEN TRILLIUM AND TRADESCANTIA

CARL P. SWANSON

THE recent reviews by Nebel (1941) and Huskins (1941) of chromosome structure and coiling are indicative of the considerable research that has been done in this special field of cytology. Nebel has stressed, in particular, the interpretation of the images obtained at the lower limits of resolution as well as the hazards involved; Huskins, on the other hand, has dwelt upon the origin and interpretation of the coiling mechanism as typified by the large chromosomes of the genus Trillium. Both of these reviews are concerned largely with the descriptive phases of the subject. It must be realized, however, as Nebel points out, that, though the more obvious structures have been resolved, further progress is likely to be slow and difficult because of the illusory images obtained of the finer details through refraction and interference. Other avenues of approach must be found to attack the problems in this field.

That our understanding of the coiling mechanism can be pushed somewhat further through the use of abnormal material and various environmental agents has been demonstrated. Huskins and Wilson (1938) and Wilson and Huskins (1939) did this in Trillium, using heat-treated, asynaptic, and desynaptic material, whereas Swanson (1942 a, b), using Tradescantia, employed heat and ultraviolet treatments. The picture obtained in Tradescantia differs considerably from that presented by Wilson and Huskins (1938) in Trillium, but agrees with unpublished observations which the writer has made in other plant and animal materials. It is the purpose of this paper to enlarge upon earlier observations (Swanson, 1942a), and to present new material pertinent to the subject of chromosome coiling. The technical details of the experiment have been previously described (Swanson 1942a).

MEIOTIC COILING IN TRADESCANTIA

It has been a common observation in a variety of organisms, Trillium excepted (Wilson and Huskins, 1939; Huskins, 1941), that the overall chromosome length is progressively reduced between pachytene and metaphase. In Osmunda (Manton, 1939) this shortening is considerable, the metaphase chromosomes being only one eighteenth of their pachytene length. In Tradescantia the reduction, not quite so extreme, is nearer to one tenth for meiotic, and to one third to one fifth for mitotic, chromosomes (Sax and Sax, 1935). The theory generally held is that the contraction is due to the formation of a coiled condition by the previously uncoiled pachytene thread; this is implied by the appearance of a regularly spiraled metaphase chromosome.

With the exception of Trillium (Huskins, 1941, for review) there is but little literature dealing with the time interval of coiling between pachytene and metaphase. Darlington (1939) makes the general statement that large coils arise from smaller ones — a statement to which the writer wholly subscribes — but there are no experimental data bearing on this subject outside of Koller's (1938) observations on mitotic coiling in the golden hamster and a preliminary report on Tradescantia (Swanson, 1942a). Several questions might be raised at this point. How does the major coil arise? What is the origin of the minor coil and what is its temporal relationship to the major coil? What is the behavior of these two kinds of coils once they have been formed? What rôle does the matrix play in chromosome coiling? An attempt will be made to answer these questions, at least in part.

In Tradescantia it is possible to approach these problems through the application of heat, more especially, heat shocks at 40° C. At normal temperatures seven to eight coils per chromosome are characteristic (Pl. I A); high temperatures strikingly alter the coiling behavior. Either the coils are more numerous (Pl. I B) or less numerous (Pl. I C) or they exhibit an unstable condition, stretching out under anaphase tension (Pl. I D). The latter condition has been interpreted as resulting from lessened viscosity of the matrix, whereas the other two are derived from a condition in which the chromosomes and spindle are out of step with each other. Their usual coördinated behavior is disrupted by a speeding up or a slowing down of the

coiling or spindle development (Fig. 1), leading to elongated or greatly contracted chromosomes. Piecing together the varied heat-induced phenomena into an integrated whole permits one to visualize the coiling mechanism as it operates in both time and space. Meiotic coiling in Tradescantia appears to take the following course.

In early diplotene the relatively straight and, to all visible appearances, uncoiled homologous chromonemata develop a series of fairly regularly spaced minute spirals which are destined to become the major coils of metaphase. Each chromatid behaves as a separate unit (Pl. I E), and, contrary to Darlington (1937), is not coiled relationally around its sister chromatid, at least from the centromere to the nearest chiasma. This condition permits of paranemic separation of chromatids at anaphase. The freedom of chromatids implies that during the elongation that occurs between leptotene and pachytene (Belling, 1928; Manton, 1939) the relational coil resulting from the somatic coils of the premeiotic anaphase (Sparrow, Huskins, and Wilson, 1941) must have been eliminated by the straightening-out and rotation of the chromosome ends. Manton (1939) considers relational coiling to be present at pachytene in Osmunda, but no evidence bearing on this question has been seen in the present material. Wilson and Huskins (1939) state that, since the chromatids are closely associated during spiralization, they should coil in unison and similarly. Though this is generally the rule in Tradescantia, several instances have been noted of a difference in direction of coiling in sister chromatids, a condition that emphasizes in a striking manner their independence in coiling.

The sister half-chromatids also appear to be paranemically coiled (Pl. I F). The chromonemata have been so despiralized and relaxed by the heat as to permit a lateral separation of the split halves of chromatids. Matsuura and Haga (1940) have likewise shown that heat treatments can bring about a separation of sister half-chromatids (their ultramitotic type), but in view of the fact that each of these experiments has employed the use of heat, it would be premature to state that these observations invalidate the demonstration of plectonemically coiled sister half-chromatids in Trillium (Sparrow, Huskins, and Wilson, 1941), particularly since the Tradescantia microspore chromosomes show a similar relational coil under normal conditions.

The mechanism responsible for major coil initiation is unknown.

No preliminary waviness preceding a regularly formed spiral, such as has been demonstrated by Huskins (1941) in Trillium, has been found in Tradescantia. It may be, however, that this is because the present observations have not included the earliest stages, for in the camel cricket, which has a modified Tradescantia type of coiling (Swanson, unpubl.), a general waviness precedes the assumption of a regular coil (Pl. I; compare G and H).

The initiation of the major coils at diplotene constitutes the *spiralization* phase of the coiling cycle as distinguished from the later, or *despiralization*, phase (Swanson, 1942a). It is not known whether spiralization is accomplished with or without the rotation of chromosome ends. The lateral separation of chromatids at anaphase prompted Sax and Humphrey (1934) to suggest that no such rotation occurred, but since the chromatids behave separately this assumption is no longer necessary. The rôle of the matrix is problematical. If, as many workers have suggested, it determines the coiling behavior, it would appear that each chromatid must have its own matrix to coil autonomously. Kuwada (1939) considers coiling to be paralleled by a progressive dehydration of the chromosome, but whether the dehydration takes place in the chromonema or the matrix or in both is as yet undetermined.

The spiralization phase is of short duration, and is followed immediately by the despiralization phase. There is probably no time lag between the two phases because the latter is, paradoxically, but a continuation of the former, as can easily be demonstrated with a flexible wire model. It is characterized by a decrease in the number of coils, an increase in their diameter, and a marked shortening in overall chromosome length. These features are quantitatively demonstrable by a comparison of various prophase stages. It is at this stage of the coiling cycle that heat shocks (at 40° C.) are particularly effective, causing, as they do, an interruption of the coiling at different degrees of despiralization by altering the time of metaphase initiation. This temperature level probably represents, in Tradescantia, the upper limit of the chromosome-spindle coördination, and it seems very likely that its breakdown results from changes induced in the spindle-determining mechanism. A precocious spindle development brings a much-elongated chromosome to the metaphase plate (Pl. I B), whereas greatly contracted chromosomes result from a delayed spindle formation (Pl. I C). Figure 1 illustrates this graphically.

That despiralization continues well into anaphase can be shown by comparing the number of coils per chromosome at metaphase and anaphase in cells from the same anther. Anaphase counts are always smaller (Swanson, 1942a). The coil number is reduced from about

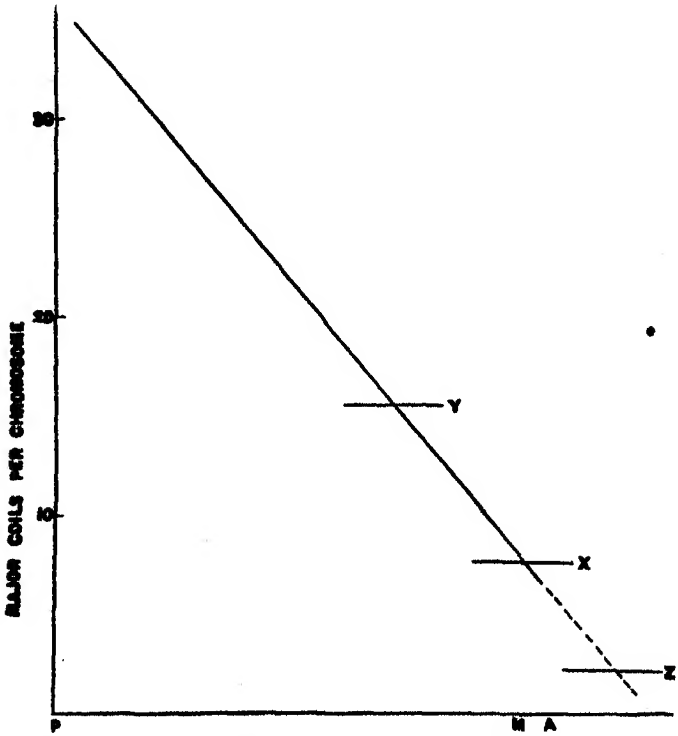


FIG. 1. The relationship of chromosome coiling to stage of division. P = prophase, M = metaphase, A = anaphase. Cross-bars (X, Y, and Z) indicate the time of appearance of metaphase in respect to coiling. X = normal metaphase, Y = precocious metaphase leading to elongated chromosomes, Z = delayed metaphase leading to greatly contracted chromosomes. The dotted part of the curve indicates the abnormal reduction in coil number resulting from a delayed metaphase

thirty-five per chromosome, the estimated number at early diplotene (Pl. I E), to seven or eight under normal conditions, or to even fewer when the spindle is delayed. Manton (1939) states that uncoiling, or despiralization, is a feature of prophase only, whether mitotic or

meiotic, and that it never occurs at telophase. In Tradescantia this is only partially correct, for though the greater portion of despiralization is accomplished at prophase, despiralization continues until temporarily arrested at interphase, and is then resumed again at the succeeding prophase. Telophase and interphase relaxation of the coils cannot, therefore, be correctly spoken of as a process of despiralization, since the hydration of the nucleus merely loosens the coils, transforming the tight formation into the laxer relational coil of the following prophase (Sparrow, Huskins, and Wilson, 1941). Since spiralization and despiralization are but different aspects of the same phenomenon, coiling must be viewed, therefore, as a constantly recurring cycle, overlapping somewhat in prophase, interrupted for variable intervals by interphase, and finally to be arrested permanently in nondividing cells. Only during the period of meiotic pairing is there a lag between the completion of one coiling cycle and the initiation of another.

The proved reality of the minor coil (Pl. I C) suggests that most, if not all, of the contraction of chromosomes in Tradescantia is due to the coiling mechanism. As indicated by changes in coil number and diameter, the prophase development of the minor coil follows much the same course as does that of the major, i.e. progressive, despiralization. The evidence, however, is open to question because the small size makes them difficult of observation. Likewise debatable are the time and the manner of minor coil initiation (the spiralization phase). The visible appearance follows that of the major coils in Tradescantia (cf. Coleman and Hillary, 1941), but if the pachytene threads are submicroscopically coiled — not too remote a possibility in view of the observations of Manton (1939) — it is possible that their origin is at some prepachytene stage. On the other hand, they may arise *de novo* in diplotene or early diakinesis. This coil becomes the second division coil, since it is not eliminated during interphase (Nebel, 1939).

MEIOTIC COILING IN TRILLIUM

A comparison of the Tradescantia coiling cycle with that of Trillium reveals a number of differences. Our knowledge of the details of Trillium coiling has resulted from the careful and extensive work of Huskins and his coworkers at McGill University.

The most obvious difference seen in this genus is the comparative

lack of chromosome shortening during meiotic prophase (Wilson and Huskins, 1939; Huskins, 1941). The initiation of the major coil is not, therefore, a causal agent in chromosome contraction, as in Tradescantia, but is itself the result of an elongation of the chromonema, an elongation which may be the expression of an actual longitudinal growth of the chromonema (Huskins, 1941) or a reduction in gyre diameter of the minor coil (Coleman and Hillary, 1941). Wilson and Huskins (1939) look upon the coil as developing when the chromonema lengthens within a bounding pellicle; Coleman and Hillary (1941), observing that the major coils are first initiated distally, consider that they arise independently of the matrix and as a result of changes inherent in the chromonema.

A second difference lies in the fact that it is impossible to separate the Trillium prophase coiling cycle into spiralization and despiralization phases, since only the former seems to exist. Once the coils are fully established there is no change in either number or diameter until the first microspore prophase, in which they are passively straightened out and lost by the development of the somatic coil (Sparrow, Huskins, and Wilson, 1941). No active despiralization occurs. It is evident, therefore, that a marked timing difference exists between these two genera. Whereas in Tradescantia the spiralization phase is completed rapidly in early diplotene and is then followed by the despiralization phase which occupies the remainder of prophase, this entire period in Trillium is taken up by the somewhat leisurely spiralization phase, which allows the coils to assume their mature proportions directly.

The question of the presence of a minor coil in Trillium seems to have been answered photographically in the affirmative by Coleman and Hillary (1941), although Huskins (1941), in his recent review, still maintains that he can detect but a slight "waviness" along the length of the chromonema. Like the major coil, it is paranemic in nature.

Trillium possesses no interphase, but retains its coiled condition into the second division telophase.

THE MATRIX

It is evident that the behavior of the matrix in Tradescantia and Trillium must be quite different. The matrix of the former has to contract in length and increase in diameter as prophase progresses;

in the latter it must behave in a more or less static fashion, with the coils developing within its unchanging boundaries. However, the dynamics of matrical behavior are as yet only poorly understood, although the recent interest in this portion of the chromosome structure (see discussion following Huskins paper, 1941) indicates a growing realization of its importance in chromosome behavior.

Sax and Humphrey (1934), Wilson and Huskins (1939), and Kuwada (1939), in their coiling hypotheses, consider the matrix to be one of the determining factors in coiling. It limits, by means of its outside boundary, the length and width of the chromosome. When it is absent, owing to heat treatment, major coiling does not occur (Huskins, 1941). Similar uncoiled chromosomes have been observed in Tradescantia, after heat shocks, but the matrical situation was undetermined. Swanson (1942b) has recently demonstrated, in the generative nucleus, that short wave-length radiation in the ultraviolet region (2537 Å) materially affects the matrix, bringing it clearly into view as a transparent hyaline structure, and at the same time visibly shortening the chromosomes. Long wave-length radiation (2967 Å and 3022 Å) had no effect on either matrix or chromosome length. It would appear that there exists a distinct correlation between matrical development and chromosome contraction, though the issue is clouded by the fact that a small percentage of cells appear in which the chromosomes are greatly contracted but in which the matrix is not visible.

In passing, it is of interest to consider the development and synthesis of the matrix. It has been generally considered that the matrix becomes more and more of a distinct entity as the division cycle approaches metaphase. This growth appears to be strikingly correlated, in a negative fashion, with the growth relationships of nucleolus, i.e. as the nucleolus decreases in size the matrix increases, and vice versa. Gates (1938) has previously suggested that a close relationship exists. Other lines of evidence support Gates' suggestion. Staining reactions show that these two structures are similarly affected by certain stains; Schultz (1941) has demonstrated chemically that the protein of the matrix of the salivary gland chromosomes is closely related to that in the nucleolus, and that ribose nucleic acids may be similarly shared; and, lastly, McClintock (1934) has proved that, when the organizer is absent, nucleolar material is released from each chromosome in the form of droplets. It is

apparent that this seemingly intimate relationship between the nucleolus and the matrix is in need of further study.

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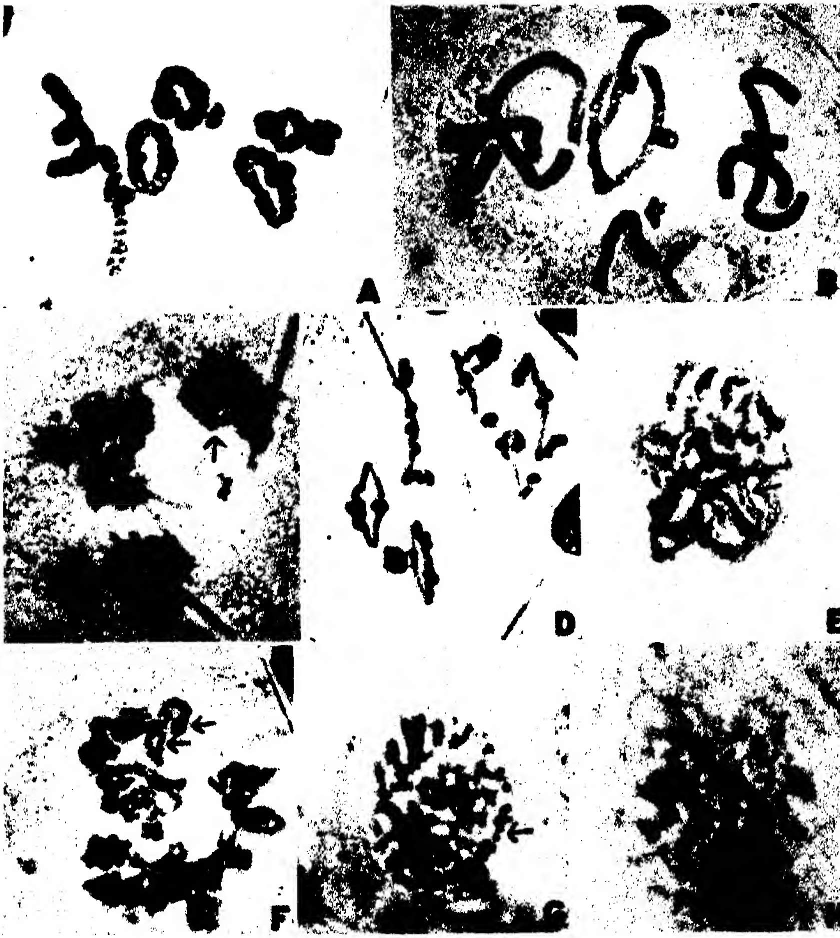

PHOTOMICROGRAPH OF MEIOTIC CELLS IN VARIOUS STAGES OF COILING

A–F. *Tradescantia canaliculata* Raf.

- A. Metaphase under normal conditions
- B. Elongated chromosomes at metaphase due to a precocious spindle. 40° C.
- C. Shortened chromosomes due probably to a delayed spindle; arrows point to the minor coils. 40° C.
- D. Major coils stretching under anaphase tension (arrow). 40° C.
- E. Diplotene. Arrow indicates separate chromatids; coils appear as chromomere-like dots. 40° C.
- F. Shortened chromosomes. Half-chromatids separating laterally. 40° C.

G–H. Camel cricket

- G. Irregular coil (arrow) formed at time of major coil initiation
- H. Regular coil, which develops at a later stage

MARINE ALGAE FROM HAITI COLLECTED BY H. H. BARTLETT IN 1941

WM. RANDOLPH TAYLOR

THE island of Hispaniola, second largest of the Greater Antilles, was long the least known of the group, so far as its algal flora is concerned. There are a few old records from the eastern Dominican Republic and a short but good account, by Børgesen, of algae from the adjacent Beata Island. On three previous occasions (Taylor and Arndt, 1929, p. 561; Taylor, 1933, p. 395; Taylor, 1940, p. 549) the writer has had opportunity to list algae from the western part of the island, in the Republic of Haiti. Including those in the account here offered, the number of algae known from Hispaniola exceeds two hundred, but this is probably less than half the total which thorough study would show. Nevertheless, we now have a tolerable idea of the flora of the western part of the island.

The present collection of material was made in 1941 by Professor H. H. Bartlett, of the University of Michigan, to whom the writer is greatly indebted for the opportunity of studying it and for the descriptions of the localities involved.

The first collection (May 1) was made south of Dame Marie toward Anse d'Hainault, at the western end of the southern peninsula. Here there is a sandy beach sloping to about 4 feet below low tide, and having an irregular bottom of sand and eroded limestone, which is exposed to a heavy surf, so that there is generally a good deal of sand suspended in the water. At the southern end hard limestone cliffs terminate the beach, descending to deep water in an exposed position. The algal flora was rather rich, with rock-attaching reef forms and a number of forms suited to tide pools having some slight protection.

The second collection (May 6) came from La Pointe, at Jérémie, on the north coast of the southern peninsula. Here wave-worn and eroded reefs of limestone and conglomerate were exposed to heavy seas. Pools in holes were filled with Turbinaria, but in general the

specimens came from shallow but very rough water. The flora was a varied one.

Trou Cochon, also near Jérémie, is a cove open to heavy seas, with a steep sand beach at the center flanked by vertical sea cliffs of hard limestone. The collections (May 9) were made from the cliffs and from large detached masses of limestone, or from floating material, and showed a good variety.

Between Jérémie and Les Roseaux, collections (May 10) were made over a limestone bottom which was partly sand-covered, being occupied by eelgrasses at a depth of 3–5 feet, with occasional deeper pools bare of grass. This was a protected station, guarded by offshore reefs in ordinary weather. The flora was not very varied, and was marked by Halimedas, Galaxauras, Codium, and similar forms which prefer quiet water.

Léogane is another station on the north shore, 32 km. west of Port-au-Prince, and the habitat was a sheltered cove behind reef and mangrove, where the sandy bottom in shallow water was overgrown by eelgrasses. The flora collected (June 1) was not a rich one, being marked chiefly by Acanthophora and Hypnea, with some Dictyota and Chaetomorpha.

On the south shore of the peninsula collections (May 13) were made at Saint Louis du Sud, where the bottom was flat and sandy to muddy, with a good deal of eelgrass in the notably warm water. The collections yielded little variety, but contained a good deal of Gracilaria, Hypnea, and Enteromorpha, as is appropriate to the type of location.

The final collection (June 23) was made on an island lying off Anse à Margot (Bayeux), on the north coast between Cap Haitien and Le Borgne. Here a narrow reef of coral, mostly dead and worn or covered with sand, stood between the sea and deeper pools full of Turbinaria; at low tide, when the reef was not covered, the water in these became quite hot. A large variety of algae were represented, but chiefly species suited to quiet water.

Discovery in one of the Bartlett collections of a gelidiaceous plant quite different from anything familiar to the writer impelled him to reconsider all of his specimens from the warmer seas of America and to borrow pertinent material from the New York Botanical Garden, for the loan of which he is greatly indebted. The result of a study of this material was the conviction that few of the American tropical

or subtropical plants can be considered identical with those from temperate waters, and that the bulk of the specimens hitherto collected had been misidentified. Without confidence that further changes may not be necessary, the writer offers in the course of this paper certain new species and new identifications as promising some clarification of the confusion of forms long known to exist in this family in the American area.

List of Species

MYXOPHYCEAE

OSCILLATORIACEAE

Lyngbya confervoides C. Agardh. — Bayeux, *17987* (det. F. Drouet).

Phormidium Crosbyanum Tilden. — Bayeux, *17996* (det. F. Drouet).

RIVULARIACEAE

Calothrix crustacea Thuret. — Les Roseaux, *17841* (det. F. Drouet).

CHLOROPHYCEAE

ULVACEAE

Enteromorpha flexuosa (Wulfen) C. Agardh. — Saint Louis du Sud, *17956.*

Enteromorpha lingulata J. Agardh. — Dame Marie, *17833;* Jérémie, *17888.*

Ulva fasciata Delile. — Jérémie, *17885.*

VALONIACEAE

Anadyomene stellata (Wulfen) J. Agardh. — Jérémie, *17875.*

Cladophoropsis membranacea (C. Agardh) Børgesen. — Dame Marie, *17844;* Jérémie, *17890;* Léogane, *17961;* Bayeux, *17985.*

Dictyosphaeria cavernosa (Forsskål) Børgesen. — Dame Marie, *17838.*

Valonia macrophysa Kützing. — Dame Marie, *17834.*

Valonia ocellata Howe. — Dame Marie, *17840;* Jérémie, *17886;* Bayeux, *17982.*

CLADOPHORACEAE

CHAETOMORPHA BRACHYGONA Harvey. — Saint Louis du Sud, *17959.*

CHAETOMORPHA CLAVATA (C. Agardh) Kützing. — Trou Cochon, *17929.*

CHAETOMORPHA GENICULATA Montagne. — Léogane, *17962.*

CHAETOMORPHA MEDIA (C. Agardh) Kützing. — Dame Marie, *17848;* Jérémie, *17887;* Trou Cochon, *17912.*

CLADOPHORA FASCICULARIS (Mertens) Kützing. — Dame Marie, *17821.*

CLADOPHORA FULIGINOSA Kützing. — Jérémie, *17891.*

CLADOPHORA HOWEI Collins. — Jérémie, *17898.*

DASYCLADACEAE

CYMOPOLIA BARBATA Lamouroux. — Bayeux, *17986.*

BRYOPSIDACEAE

BRYOPSIS PENNATA Lamouroux. — Jérémie, *17873.*

CAULERPACEAE

CAULERPA CUPRESSOIDES (West) C. Agardh. — Bayeux, *17976.*

CAULERPA CUPRESSOIDES var. MAMILLOSA (Montagne) Weber-van Bosse. — Les Roseaux, *17847.*

CAULERPA RACEMOSA (Forsskål) J. Agardh. — Bayeux, *17972.*

CAULERPA SERTULARIOIDES f. BREVIPES (J. Agardh) Svedelius. — Les Roseaux, *17846;* Bayeux, *17872.*

CODIACEAE

AVRAINVILLEA LEVIS Howe. — Trou Cochon, *17829.*

AVRAINVILLEA RAWSONII (Dickie) Howe. — Dame Marie, *17828;* Bayeux, *17993.*

CODIUM DICHOTOMUM (Hudson) Setchell. — Jérémie, *17874;* Les Roseaux, *17948;* Bayeux, *18000.*

HALIMEDA MONILE (Ellis and Solander) Lamouroux. — Dame Marie, *17854;* Léogane, *17969.*

HALIMEDA OPUNTIA (Linnaeus) Lamouroux. — Dame Marie, *17824;* Bayeux, *17983.*

HALIMEDA TRIDENS (Ellis and Solander) Lamouroux. — Les Roseaux, *17935*.

HALIMEDA TRIDENS var. TRIPARTITA (Barton) Collins. — Dame Marie, *17853*.

PENICILLUS CAPITATUS Lamarck. — Dame Marie, *17845;* Bayeux, *17979*.

PENICILLUS PYRIFORMIS Gepp. — Dame Marie, *17855*.

UDOTEA FLABELLUM (Ellis and Solander) Howe. — Dame Marie, *17837*.

PHAEOPHYCEAE

RALFSIACEAE

RALFSIA EXPANSA J. Agardh. — Dame Marie, *17863*.

DICTYOTACEAE

DICTYOPTERIS DELICATULA Lamouroux. — Jérémie, *17889;* Les Roseaux, *17941*.

DICTYOPTERIS PLAGIOGRAMMA (Montagne) Vickers. — Trou Cochon, *17917*.

DICTYOTA CERVICORNIS Kützing. — Dame Marie, *17859;* Bayeux, *17975*.

DICTYOTA CILIOLATA Kützing. — Les Roseaux, *17950*.

DICTYOTA DENTATA Lamouroux. — Trou Cochon, *17922*.

DICTYOTA DIVARICATA Lamouroux. — Dame Marie, *17823;* Léogane, *17965*.

PADINA GYMNOSPORA (Kützing) Vickers. — Dame Marie, *17860c;* Jérémie, *17902b;* Bayeux, *17978* (all det. F. Thivy).

PADINA SANCTAE-CRUCIS Børgesen. — Dame Marie, *17860a;* Jérémie, *17902a;* Léogane, *17966;* Bayeux, *17977* (all det. F. Thivy).

PADINA VICKERSIAE Hoyt. — Dame Marie, *17860b;* Les Roseaux, *17947* (both det. F. Thivy).

ZONARIA VARIEGATA (Lamouroux) C. Agardh. — Trou Cochon, *17918*.

ZONARIA ZONALIS (Lamouroux) Howe. — Dame Marie, *17843*.

FUCACEAE

SARGASSUM FILIPENDULA C. Agardh. — Trou Cochon, *17908*.

SARGASSUM FLUITANS Børgesen. — Trou Cochon, *17906*.

SARGASSUM LENDIGERUM (Linnaeus) Kützing. — Trou Cochon, *17924*.

SARGASSUM NATANS (Linnaeus) J. Meyen. — Jérémie, *17878;* Trou Cochon, *17905*.

SARGASSUM PLATYCARPUM Montagne. — Dame Marie, *17856;* Jérémie, *17876;* Trou Cochon, *17907;* Bayeux, *18003*.

SARGASSUM POLYCERATIUM Montagne. — Dame Marie, *17857;* Jérémie, *17880;* Trou Cochon, *17909;* Bayeux, *18004*.

SARGASSUM VULGARE C. Agardh. — Dame Marie, *17858;* Jérémie, *17879;* Trou Cochon, *17910*.

TURBINARIA TURBINATA (Linnaeus) Kuntze. — Jérémie, *17881;* Trou Cochon, *17911;* Bayeux, *17970*.

RHODOPHYCEAE

HELMINTHOCLADIACEAE

LIAGORA CERANOIDES Lamouroux. — Bayeux, *17973*.

LIAGORA VALIDA (Forsskål) C. Agardh. — Trou Cochon, *17930*.

CHAETANGIACEAE

GALAXAURA CYLINDRICA (Solander) Kjellman. — Les Roseaux, *17946*.

GALAXAURA FLAGELLIFORMIS Kjellman. — Bayeux, *18001*.

GALAXAURA MARGINATA (Ellis and Solander) Kjellman. — Jérémie, *17883;* Les Roseaux, *17945*.

GALAXAURA OBLONGATA (Ellis and Solander) Lamouroux. — Trou Cochon, *17923*.

GALAXAURA OBTUSATA (Ellis and Solander) Lamouroux. — Trou Cochon, *17933*.

GALAXAURA RUGOSA (Ellis and Solander) Lamouroux. — Jérémie, *17884;* Les Roseaux, *17946b;* Léogane, *17968;* Bayeux, *17997*.

GALAXAURA SQUALIDA Kjellman. — Jérémie, *17867;* Trou Cochon, *17934;* Les Roseaux, *17939;* Léogane, *17967;* Bayeux, *17900*.

GALAXAURA SUBVERTICILLATA Kjellman. — Bayeux, *17998*.

Gloiophlaea caribaea, sp. nov.[1] (Pl. I, Fig. 2). — Plant arising from a short conical base, 3–4 cm. tall, bushy, reddish brown near the

[1] **Gloiophlaea caribaea,** sp. nov. — Planta monoica, 3–4 cm. alta, fruticiformis; caule primario brevi, dichotome repetiter (10–13) ramoso, ramulis deorsum 0.5–0.7 mm. crassis sursum prope apicem 1.25 mm. crassis; axi ex filamentis multis crassiusculis inter alia tenuiora formantia corticem interiorem

tips of the branches, much darker below; the primary stem short, the branching above dichotomous, with members of some forkings surpassed in development by those of others, the divisions to 10–13 stages at least; when dried the branches 0.25 mm. diam. near the base of the plant and 0.80 mm. near the tips, when soaked, up to 0.50–0.70 mm. diam. below and up to 1.25 mm. near the tips; axis consisting of many stouter filaments 6–14 μ diam., with relatively thick walls, loosely disposed in an area 250 μ diam. and having among them many more slender filaments, about 2 μ diam., which continue out to form the loose inner cortex; outer cortex about 33 μ thick, with one layer of ovate-turbinate colorless utricles supported by an inner layer of large oval cells, which, in converging series, are connected in a few stages with the slender filaments by small rounded cells; slender colored filaments penetrating between the utricles; monoecious, the spermatangia widespread, formed in the younger parts of the plant on the ends of the superficial filaments between the utricles; cystocarps abundant, first appearing only one or two forkings below the branch tips, mature in the middle portion of the plant, subspherical or depressed, 160–175 μ diam., with 5–8 layers of coherent filamentous pericarp.

Type. — Trou Cochon, west of Jérémie, *H. H. Bartlett 17920*, May 9, 1941, in Herb. Univ. Mich.

These specimens come close to *Gloiophlaea Halliae* Setchell (1914, p. 116) in microscopic characters, differing chiefly in the prominence of the axial strands and in the size of the cystocarps. Macroscopically the differences are more marked. The plants in the present collection, in spite of being only about a third as tall as Setchell's species, branch twice as often, so that the segments average much shorter, the distance between the forks being in general only 2–3 mm. and in but one case reaching 5 mm. The diameter of the segments, too, seems only about half of that in his plants. It is not inconceivable that the variations are within

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constante; cortice exteriore ca. 33 μ crasso, extus constante ex utriculis pellucidis ovato-turbinatis, intus ex cellulis magnis ovalibus somata chromatophora includentibus; spermatangiis ubique dispersis in ramulis junioribus; cystocarpiis abundanter in parte plantae media maturantibus, diametro ca. 160–175 μ, vestitis cum laminis 5–8 filamentosis pericarpialibus cohaerentibus. Habitat in loco dicto Trou Cochon prope Jérémie, Haiti, legit H. H. Bartlett, n. 17920, 9 Mai., 1941; specimen typicum in Herb. Univ. Mich. conservatum.

the range of one species, but, with only two collections known, that can hardly be established.

GELIDIACEAE

GELIDIELLA ACEROSA (Forsskål) Feldmann and Hamel. — Jérémie, *17822;* Dame Marie, *17850;* Les Roseaux, *17942;* Saint Louis du Sud, *17952;* Bayeux, *17999.*

Gelidiella trinitatensis, sp. nov.[2] (Pl. I, Fig. 1). — Plant minute, the basal filaments entangled, cylindrical, about 55–75 μ diam., with erect cylindrical or compressed filaments up to 2, rarely 5, mm. tall, 75–90 μ diam., simple or irregularly and sparingly branched, terminally or laterally bearing cylindrical to generally flat simple or pinnate to subpalmate tetrasporangial branchlets; tetrasporangia originating in clear V-shaped rows, later obscured, near the apices, the spores being shed first from the lower portions of the branchlets.

Type. — Manzanilla Point, Trinidad, British West Indies, *R. Thaxter,* April 14, 1913 (Taylor, 1929, p. 623, as *Gelidium crinale*), in Herb. W. R. Taylor.

In this family the first new entity, *Gelidiella trinitatensis,* is a minute creeping plant which probably came from rocks in shallow water along shore, since fragments of Bryocladia are mixed with it. Until the arrangement of the sporangia is noted this plant might be mistaken for a form of *Gelidium pusillum* lacking flat blades, or for a miniature *Gelidium crinale.* It seems amply distinct from either of these and nearest *Gelidiella tenuissima* Feldmann and Hamel (1936, p. 226), for the stem structure is similar in section and most of the superficial characters are likewise in agreement. The fertile branchlets in that species are not forked, however, as here, nor are the erect branches compressed.

[2] **Gelidiella trinitatensis,** sp. nov. — Planta minuta, filamentis basalibus cylindricis, repentibus, intertextis, ca. 55–75 μ crassis; filamentis erectis cylindricis vel compressis, plerumque 2 mm., raro 5 mm., altis, 75–90 μ crassis, simplicibus vel irregulariter sparse ramosis, ad apicem vel secus ad latera tetrasporangiales ramulos saepe cylindricos vel plerumque compressos, simplices vel pinnatos vel subpalmatos ferentibus; tetrasporangiis in seriebus regulariter V-formibus prope apices formantibus, deinde irregulariter dispositis; sporis in parte ramulorum inferiore primum maturantibus. Habitat in loco dicto Manzanilla Point, I. Trinidad, British West Indies, legit R. Thaxter, 14 Apr., 1913; specimen typicum in Herb. W. R. Taylor conservatum.

When the plants of *Gelidiella trinitatensis* under study showed very small tetrasporangial sori on cylindrical branches, the branches appeared stichidium-like. Where the branchlets were simple but more productive they became band-shaped and about 85–90 μ wide by 400–500 μ long, with the V-shaped rows of sporangia and, at the oldest stages, very evident sporangial cavities. The forked branchlets were sometimes flat, sometimes, if narrow, only compressed. One fragment associated with this material but not seen to be attached to the same horizontal filaments may represent a further development. It consisted of a flat linear-oblanceolate blade 8 mm. long, 375 μ diam., with nine similar linear-lanceolate branchlets pinnately crowded near the tip, and two isolated smaller ones below. These were fertile near the tips, the linear sporangial portion reaching 1.25 mm. in length.

Gelidium corneum (Hudson) Lamouroux

This plant has been reported from many places in the Americas, but not, so far as the writer is aware, from Haiti. He was inclined to identify one of the specimens of the present series as *Gelidium corneum*, in conformity with other specimens so identified by him in the past, and in making an examination of transverse sections found among his materials some with the stem structure and cystocarp structure of Gelidium; others, however, resembled Pterocladia. The structure of the stem was often confusing, but the net result was that he could confirm from materials available to him only a very few records of *G. corneum* and found it necessary to move most of the specimens to Pterocladia. Records which seem without doubt correctly assigned to Gelidium, and which are probably correctly placed under *G. corneum*, are noted below.

Distribution. — Panama: Careening Cay, *Dodge 75*, Sept. 7, 1925 (cystocarpic). Martinique: *G. Hamel and A. Hamel-Joukov 84*, March, 1930 (tetrasporic).

These specimens are clearly pinnately branched, with regular gradations of branches from the tips. The cystocarpic specimens tended to be more consistently twice-pinnate than the tetrasporic ones. The structure was obviously cartilaginous, and the branches were quite thick for their breadth. In section the slender refractive filaments called "rhizines" were more or less restricted to the outer tissues.

GELIDIUM CRINALE (Turner) Lamouroux var. **platycladum,** var. nov.[3] (Pl. II, Fig. 1). — Plants to 7–10 cm. tall, dark reddish purple, the base with a few flagelliform branches, mostly erect, the main axes often being twisted together, flat except at the extreme base, to 550 μ wide and 125 μ thick, but somewhat broader at the forkings; in section rhizines few, inconspicuous, and in the outer part of the central tissue; branching irregularly dichotomous below, seemingly alternate above, the ultimate divisions subcorymbosely crowded, acute-tipped; cystocarps not conspicuous, bilocular, in the ultimate or penultimate branchlets, causing a swelling on both faces; tetrasporangia in the acute, very slightly expanded branchlets of the last two or three divisions, irregularly placed, discharging from the apices first and only later in the lower parts of the sori, the tips sometimes decaying.

Type. — Port Aransas, Texas, *C. J. Reed 47*, May 20, 1932, in Herb. W. R. Taylor.

Distribution. — TEXAS: Galveston, *Smith*, June, 1937; Goose Island, *Smith*, Oct., 1937; Rockport, *Reed*, Jan., 1936; Port Aransas, *Sanders 4, 6*, April, 1931, in Herb. N. Y. Bot. Gard., Herb. W. R. Taylor; Corpus Christi, *Reed*, Feb., 1939; Boca Chica, *Clover*, Aug. 8, 1932, in Herb. Univ. Mich. FLORIDA: St. Augustine, *Reynolds*, no date, in Herb. N. Y. Bot. Gard.; Hillsborough Bay, *McFarlin*, May, 1931, in Herb. Univ. Mich.; Pensacola, *Belknap*, no date, in Herb. N. Y. Bot. Gard.

These plants differ strikingly from *Gelidium crinale* of northern waters. They are much more robust, and the axes are for the most part flattened except at the base, whereas in typical *G. crinale*, which is ordinarily cylindrical, they may occasionally show a little compression. The branchlets are more markedly clustered, sometimes in quite congested groups, and in the tetrasporangial plants are much more sharp-tipped. Flattening of the tetrasporangial branches is not conspicuous, the fertile portion being

[3] *Gelidium crinale* (Turner) Lamouroux var. **platycladum,** var. nov. — Plantae plerumque 7–10 cm. altae, ramis erectis principalibus planis, basi ultima excepta, sursum alterne ramosis; ramulis ultimis subcorymbose aggregatis, apice longe acutissimeque apiculatis; tetrasporangiis positis in divisionibus 2 vel 3 ultimis et paene ultimis; ramulis eis subultimis tetrasporiferis vix expansis sed compressis, pinnatis vel palmatis; apicibus acutis. Habitat in loco dicto Port Aransas, Texas, U. S. A., legit. C. J. Reed, n. 47, 20 Mai., 1932; specimen typicum in Herb. W. R. Taylor conservatum.

merely a continuation in shape of the vegetative axis, and so differing from the northern form, where the expansion of the sporangium-bearing part is evident. Some tropical and subtropical specimens, however, agree with those from the north, and the differences are interpreted as varietal. Børgesen (1934, p. 3; 1939, p. 106) has described under the name *G. heteroplatos* a parallel form from India.

Gelidium floridanum, sp. nov.[4] (Plate III, Figs. 1–2). — Base ramified, the entangled branches cylindrical, reflexed and somewhat flagelliform, basal branches giving rise to erect subsimple strap-shaped branches which at full development become about 1 mm. wide, 13 cm. tall, sparingly pinnately branched below, commonly regularly distichous in the upper portions of well-grown plants; sections of main branches showing numerous rhizines more or less in small groups scattered through the central and the peripheral tissue, but somewhat more abundant in the peripheral; sterile branchlets spreading, strap-shaped, contracted at the base and obtuse at the apices; fertile branchlets in crowded pinnate clusters on the lower portions of the main branches; tetrasporic branchlets at first simple, obovate, becoming ligulate, then pinnately branched, with the sorus occupying the central portion of the branchlets, surrounded by a firm sterile border; cystocarpic branchlets with one, seldom two, cystocarps in each branchlet, becoming pinnate, the cystocarps bilocular, swollen and with a slightly projecting ostiole; after discharge of tetraspores or of carpospores the fertile segments often becoming perforate.

Type. — Indian River, Florida, *E. Palmer 47*, 1874 (tetrasporic), in Herb. N. Y. Bot. Gard.

Distribution. — FLORIDA: Cape Malabar, *F. A. Curtiss*, no

[4] **Gelidium floridanum,** sp. nov. — Planta erecta matura 13 cm. alta, ramis primariis compressis, ca. 1 mm. latis, deorsum sparse pinnatque ramosis, sursum distiche ramosis, in sectione transversali filamenta rhizoidalia ("rhizina" auctorum recentiorum) ostendentibus, eadem fasciculos parvos in partibus interioribus et exterioribus formantia; ramulis sterilibus patentibus, liguliformibus, basi contractis; ramulis fertilibus in greges pinnatos aggregatis in parte ramorum principalium inferiore; ramulis tetrasporiferis ultime pinnatis, soros centrales margine sterili cinctos ferentibus; cystocarpiis bilocularibus singulis vel binis in segmento singulo ramulorum ultime pinnatorum. Habitat in loco dicto Indian River, Florida, U. S. A., legit E. Palmer, n. 47, 1874; specimen typicum in Herb. N. Y. Bot. Gard. conservatum.

date, in Herb. N. Y. Bot. Gard.; Oceanus, *A. H. Curtiss*, July, 1876 (cystocarpic), in Herb. N. Y. Bot. Gard.; Indian River, *Palmer 47*, 1874 (several specimens, cystocarpic and tetrasporic) in Herb. N. Y. Bot. Gard. TRINIDAD: Maqueripe Bay, *Thaxter*, 1912–13 (tetrasporic).

This plant strongly resembles *Gelidium clavatum* Okamura (1934, p. 61, pl. 28). It differs in the more regularly pinnate narrower fronds, and in the very notable congestion of the reproductive branchlets, a feature not described for Caribbean Gelidia.

Pterocladia americana, sp. nov.[5] (Pl. IV, Fig. 1). — Plant stoloniferous below with a subcylindrical horizontal axis, this feature being inconspicuous in luxuriant tufts; the basal portion giving rise to simple erect flat blades to 0.5–2.0 cm. tall or to blades more or less pinnately branched; in bushy plants of larger size, up to 5–6 cm., the axis sparingly pinnately branched and rebranched, becoming obscure in the tetrasporangial plant, where the branches are fastigiate, but in the sexual plants frequently more regularly pinnate, though the upper branches often seem palmate by reason of condensation of the axis; the branchlets tending to appear erect, their bases subcylindrical, somewhat contracted and at first upcurved, though later spreading, flat in the distal portion, to 500–650 μ wide and 75–150 μ thick; all axes quite flat, often submembranous, with the rhizines chiefly in the central region; tetrasporangia in all growth forms, in the simple blades occupying the distal portion, the sporangia originating in clear V-shaped rows; in the smaller crowded branching plants the sporangia appearing in practically unmodified branchlets of the last 1–2 orders, again occupying the full width of the thin blades; the cystocarps causing a slight broadening of the branchlet bearing them, a slight swelling on the ventral, and a marked one on the dorsal surface, where the ostiole is eventually somewhat raised; only one chamber and one spore group.

[5] **Pterocladia americana, sp. nov. — Planta interdum 5–6 cm. alta, fruticosa, pinnate sparse ramosa; ramis fastigiatis, erectis, basi subcylindricis, paulum contractis curvatisque, sursum plantis non plus quam 500–650 μ latis, 75–150 μ crassis; tetrasporangiis in ramulis ordinariis ultimis vel paene ultimis positis, in seriebus primum V-formibus sed irregularibus et prope maturitatem deinde plus minusve inordinatis; ramis apice obtusis, aetate filamenta rhizoidalia plerumque axialia ostendentibus. Habitat in loco dicto Port Antonio, Jamaica, legit Pease et Butler, Phyc. Bor.-Am. n. 783, Jul., 1900 (sub nom. *Gelidium caerulescens* Crouan); specimen typicum in Herb. W. R. Taylor conservatum.**

Type. — Port Antonio, Jamaica, *Pease and Butler*, Phyc. Bor.-Am. *783*, July, 1900 (sub nom. *Gelidium caerulescens* Crouan), in Herb. W. R. Taylor.

Distribution. — NORTH CAROLINA: Beaufort, Fort Macon, *Hoyt*, Aug. 20, 1906, in Herb N. Y. Bot. Gard.; Duncan Breakwater, *Hoyt*, Sept. 15, 1906, in Herb. N. Y. Bot. Gard.; Shark Shoal Breakwater, *Blomquist 11436*, Oct. 19, 1940 (all three being dwarf forms). BERMUDA: Tuckers Town, *Hervey*, Phyc. Bor.-Am. *2182a*, Feb. 24, 1915 (slender form). JAMAICA: Port Antonio, *Pease and Butler*, July, 1891, in Herb. N. Y. Bot. Gard. BARBADOS: Bathsheba, *Vickers 119*, Jan. 26, 1903 (a dwarf form), in Herb. N. Y. Bot. Gard. TOBAGO: Buccoo Reef, *Taylor 39–558c*, April 20, 1939 (an extreme dwarf form), in Herb. Univ. Mich. TEXAS: Port Aransas, *Sanders 5*, March 27, 1937, in Herb. Univ. Mich. COSTA RICA: Piuta Point, *Dodge 11*, March 20, 1930 (a dwarf form). VENEZUELA: Cubagua Island, *Taylor 39–473*, April 14, 1939 (an extreme dwarf form), in Herb. Univ. Mich.

Material of this species has passed under the name *Gelidium caerulescens* for some time. Although the name is quite often ascribed to the Crouans (in Mazé and Schramm, 1870, p. 199), they are not its authors, but rightly refer it to Kützing (1868, p. 19, pl. 56 c–d), whose type came from New Caledonia, and they do not describe the Guadeloupe plant for which they use this name in any of the editions of the Guadeloupe flora to which they contributed, but merely mention its color. Examination of material from New Caledonia in the Herbarium of the New York Botanical Garden shows that it has typical Pterocladia structure, but apparently is sterile; this material, dating from Vieillard, 1863, is marked by Howe, in pencil, "cotype," which is probably correct. One notes that Weber–van Bosse (1913–28, p. 225) refers Kützing's plant to *G. corneum*, which certainly cannot be the disposition of the Jamaican plant. Close examination of American collections shows significant differences from Kützing's figure, and altogether it appears advisable to treat the American material as distinct. Børgesen (1916, p. 114) refers the Crouan plant to *G. corneum* var. *pinnata* (Hudson) Turner, which name Feldmann and Hamel (1936, p. 254) cite as a synonym of *P. capillacea* (Gmelin) Bornet and Thuret. The American material

does not closely resemble the figure of Børgesen's Virgin Island plant, which, since he designates the position of the "hypha-like filaments" — rhizines — as central, may well be a young stage of *P. capillacea.* Collins (1901, p. 252) states that Bornet had compared the Jamaican material with that from Guadeloupe and considered it to belong to the same species. Distinctive are the erect flat branches which divide and redivide pinnately without emphasis on any dominant main axes and with a tendency for the lower branches to reach a level with the others, so that the pinnate character is obscured except in the minor branches. In some Bermuda material probably belonging here, but of exceptional growth, the branch tips are elongated and attenuate.

Apparently this is a species adapted to a variety of conditions. On exposed rocks near low-water mark it may form close tufts or even mats, with the erect branches short and comparatively simple; in this state it is often much intermixed with sand. In tide pools or other protected situations it may grow considerably larger and develop the more elaborate branch system described. The writer found numerous specimens attributed to *Gelidium pusillum* which were the simpler form of this species, and would judge that it is a common plant on rocks in this dwarf state and that it relatively rarely becomes fully developed.

Pterocladia Bartlettii, sp. nov.[6] (Pl. IV, Fig. 2). — Plant dull purplish, bushy, somewhat entangled, very slender in all parts, arising from a minute flattened holdfast, from which grow one or a few cylindrical or compressed rhizomatous branches a few millimeters in length, which bear secondary holdfasts and which at first give rise to erect linear-lanceolate simple blades, up to 1 cm. in length, that soon develop into the adult ramification; mature axes to 6–8 cm. tall, several from a common base, tapering

[6] **Pterocladia Bartlettii,** sp. nov. — Planta fruticiformis plus minusve intertexta, omnibus partibus gracillima, basi ramos breves rhizomatosos ferens; axibus maturis pluribus ex ramo rhizomatoso 6–8 cm. altis utrinque angustatis, deorsum compressis vel planatis fere 0.5 mm. latis, sursum 125–170 μ crassis ramos subsidiarios bifarie alternos principalibus similes ferentibus; ramulis inter se propinquis, divaricatis vel ascendentibus, linearibus, 2 vel 3, raro 5, mm. longis, planis, apiculatis, tetrasporangia in seriebus V-formibus ferentibus; cystocarpiis unilocularibus, singulis vel raro binis positis in ramulis ultimis planis mox a latere ostiolum vix elevatum ferente flexis. Habitat in loco dicto Saint Louis du Sud, Haiti, legit H. H. Bartlett, n. 17960, 13 Mai., 1941; specimen typicum in Herb. Univ. Mich. conservatum.

to each end, compressed below, flat above, to 0.5 mm. or a little more wide and to 125–170 μ thick, bearing alternately and bilaterally numerous subsidiary axes of one or sometimes two degrees, similar to the primary but less flat, which become erect and more or less entangled below, free above; medullary filaments involved by very abundant intercellular rhizines, which dominate the interior two thirds of the axis structure; main axis and subsidiary axes closely beset with generally divaricate, occasionally ascending, branchlets in bilateral series along the margins, these sometimes, and especially above, very regular and comblike, sometimes less regularly placed and, when elongate, irregularly deflected; branchlets linear, usually flat, minutely apiculate, when small oblanceolate, when older ligulate to spathulate, the margins entire or in broader examples obscurely and irregularly serrate, but in some specimens subcylindrical and tapering, generally to 2–3 mm. long, occasionally in isolated instances to 5 mm. long; tetrasporangia in the ultimate branchlets, near the base of the plant formed in stichidium-like enlargements of the ends of the cylindrical or compressed branchlets, where they occupy the outer, or eventually the major, portion, appearing in obvious V-shaped series which become obscured as the sporangia mature; spermatangia not seen; cystocarps unilocular, produced singly or occasionally two in the generally flat ultimate branchlets, which become strongly dorsoventrally curved, the slightly elevated ostiole being formed on the dorsal side somewhat forward of the carpospore mass.

Type. — Saint Louis du Sud, Haiti, from warm quiet shallow water along the shore, *H. H. Bartlett 17960*, May 13, 1941, in Herb. Univ. Mich.

Distribution. — TEXAS: Copano Bay, *Smith 232*, Aug. 17, 1937 (Taylor, 1941, p. 75, as *Gelidium crinale*). HAITI: Miragoane, *C. H. Arndt 204a*, Feb., 1929; Aquin, *C. H. Arndt 118, 130*, Jan., 1929 (Taylor, 1929, p. 658, as *G. crinale*); Torbeck, *Orcutt 9607*, 1929 (Taylor, 1933, p. 404, as *G. crinale*), in Herb. Univ. Mich.

This species is readily distinguished when full grown, because it is much more slender than any other of like stature. When ill developed, however, it may cause considerable trouble, which is also true of others in the genus.

PTEROCLADIA CAPILLACEA (Gmelin) Bornet and Flahault (Pl. II, Fig. 2).

Distribution. — HAITI: Bayeux, *Bartlett 17984*, June 23, 1941, in Herb. Univ. Mich. SANTO DOMINGO: San Pedro de Macoris, *Rose*, March 30, 1913, in Herb. N. Y. Bot. Gard. TRINIDAD: Maqueripe Bay, *Thaxter*, 1912–13. VENEZUELA: *Kuntze*, no date, ex Herb. P. Magnus, in Herb. N. Y. Bot. Gard. BRAZIL: Rio de Janeiro, *Rawitscher*, in Herb. Univ. Mich. URUGUAY: Isla Gorriti, *Felippone 194*, Oct. 22, 1900, in Herb. N. Y. Bot. Gard.

This plant, under the synonym *Gelidium corneum* var. *pinnatum* (Hudson) Turner, has been reported from Brazil and the Virgin Islands. In the three herbaria used for this study by fâr the larger number of specimens labeled *G. corneum* and coming from the area under consideration were assignable to *Pterocladia capillacea;* only a few were selected to illustrate the range cited above. In papers by Howe and by the writer these plants have been referred to *G. corneum*, but the structure of the cystocarp, the tetrasporangial branch, and the stem axis support the present determination. The distribution of the rhizines in the stem is by no means clear-cut in many cases, and as a character must be used with caution. When young, specimens of *P. capillacea* are not always to be distinguished at a glance from *P. americana*, described above, page 154. In general, they are coarser and the primary axes are far more distinct. The lateral branching is more regular, tending to produce a flat triangular blade, sometimes broad, but more characteristically narrow. At times there are very few branchlets, even on tall axes, but the writer finds no tendency toward a mosslike dwarf state, which is notable in *P. americana*. The range appears to be more strictly southern.

WURDEMANNIA MINIATA (Draparnaud ex de Candolle) Feldmann and Hamel var. **planicaulis**, var. nov.[7] — Plants to 8 cm. tall, bushy, blackish purple when dried, somewhat flagelliform-rhizomatous at the base, the erect axes very sparingly branched,

[7] *Wurdemannia miniata* (Draparnaud ex de Candolle) Feldmann and Hamel var. **planicaulis**, var. nov. — Plantae ca. 8 cm. altae, basi flagelliformi-rhizomatosae, axibus erectis sparse et irregulariter vel interdum opposite pinnatis, utrinque cylindricis sed in media parte valde compressis, interdum 1.1 mm. latis sed plerumque 0.5 mm. latis, 185 μ crassis. Habitat in loco dicto Jérémie, Haiti, legit H. H. Bartlett, n. 17896, 6 Mai., 1941; specimen typicum in Herb. Univ. Mich. conservatum.

irregularly alternate, occasionally opposite, pinnate, cylindrical near the ends, clearly compressed in the larger portions near the center of the plant, where the width may reach 1.1 mm., though usually half as much, and the thickness 185 μ; the growing tips showing clearly the fountain type of apical growth; sections of the older stems having a surface layer with radially somewhat elongated cells, then a medulla with the cells increasingly large and free from chromatophores toward the center, where the walls are moderately thick.

Type. — Jérémie, Haiti, from rocks in shallow rough water, *H. H. Bartlett 17896*, May 6, 1941, in Herb. Univ. Mich.

Distribution. — Jamaica: Kingston, *Orcutt 6383b*, 1927–28. Haiti: Jérémie, *Bartlett 17893, 17896*, May 6, 1941. Trinidad: Sylvia Bay, *Newcombe 789*, May 15, 1938. Brazil: Ilha Govenador near Rio de Janeiro, *Schmitt 63*, Sept. 1, 1925. The Jamaica and Brazil specimens have been reported by the writer (1931, p. 302; 1933, p. 400; both as *Wurdemannia setacea* Harvey).

This material was thought to be a Gelidium until examination of the growing tip showed that the structure was of a different type; close comparison revealed that the anatomy of the axis was the same as that of Wurdemannia. The flattened character of the branches was not in accord with the descriptions of the American material of that plant, and so reëxamination of the writer's considerable suite of specimens from Florida was made. A slight compression was recognizable in two or three, but nothing very marked. In the present material from Haiti the axis was many cells wider than thick, as the surface measurements would suggest. The walls of the central cells were not thinner than those toward the outer part of the axis, as Feldmann and Hamel (1936, p. 262) have figured them, but remained moderately thick; this is as true of the more typical Florida material as it is of the proposed new variety.

RHIZOPHYLLIDACEAE

Ochtodes secundiramea (Montagne) Howe. — Dame Marie, *17831*.

SQUAMARIACEAE

Peyssonnelia Dubyi Kützing. — Bayeux, *18010*.

MELOBESIACEAE

Fosliella farinosa (Lamouroux) Howe. — Jérémie, *17856*.
Goniolithon Boergesenii Foslie. — Bayeux, *18007*.
Goniolithon decutescens (Heydrich) Foslie. — Bayeux, *18008*.
Goniolithon solubile Foslie and Howe. — Bayeux, *18005*.
Lithothamnion floridanum Foslie. — Dame Marie, *17864*.
Melobesia membranacea (Esper) Lamouroux. — Dame Marie, *17819;* Les Roseaux, *17936;* Saint Louis du Sud, *17955*.

CORALLINACEAE

Amphiroa fragilissima (Linnaeus) Lamouroux. — Dame Marie, *17853;* Les Roseaux, *17943a;* Bayeux, *17992*, *18002*.
Amphiroa Hancockii Taylor (*in press*, 1942). — Bayeux, *18006*.
Amphiroa Tribulus (Ellis and Solander) Lamouroux. — Bayeux, *18009*.
Corallina cubensis (Montagne) Kützing. — Trou Cochon, *17931*.
Corallina subulata Ellis and Solander. — Les Roseaux, *17940*.
Jania adherens Lamouroux. — Les Roseaux, *17943*.
Jania rubens (Linnaeus) Lamouroux. — Dame Marie, *17851;* Trou Cochon, *17932*.

GRATELOUPIACEAE

Grateloupia filicina (Wulfen) C. Agardh. — Trou Cochon, *17916*, *17927*.

SOLIERIACEAE

Agardhiella tenera (J. Agardh) Schmitz. — Jérémie, *17869*.

HYPNEACEAE

Hypnea musciformis (Wulfen) Falkenberg. — Dame Marie, *17835;* Jérémie, *17874;* Trou Cochon, *17926;* Saint Louis du Sud, *17957;* Léogane, *17964;* Bayeux, *17995*.
Hypnea spinella (C. Agardh) Kützing. — Dame Marie, *17822;* Jérémie, *17897*.

GRACILARIACEAE

Gracilaria confervoides (Linnaeus) Greville. — Dame Marie, *17832*.

Gracilaria damaecornis J. Agardh. — Saint Louis du Sud, *17953*.

Gracilaria ferox J. Agardh. — Bayeux, *17988*.

Gracilaria foliifera (Forsskål) Børgesen. — Dame Marie, *17827;* Les Roseaux, *17937;* Saint Louis du Sud, *17954*.

Gracilaria mamillaris (Montagne) Howe. — Jérémie, *17870*.

GIGARTINACEAE

Gigartina acicularis (Wulfen) Lamouroux. — Jérémie, *17900*.

RHODYMENIACEAE

Coelothrix irregularis (Harvey) Børgesen. — Dame Marie, *17839;* Bayeux, *17974*.

CERAMIACEAE

Centroceras clavulatum (C. Agardh) Kützing. — Les Roseaux, *17842;* Jérémie, *17868;* Trou Cochon, *17928;* Saint Louis du Sud, *17958*.

Ceramium nitens (C. Agardh) J. Agardh. — Dame Marie, *17836;* Jérémie, *17892*.

Ceramium subtile J. Agardh. — Jérémie, *17871*.

Spermothamnion gorgoneum (Montagne) Bornet. — Les Roseaux, *17949*.

Spyridia filamentosa (Wulfen) Harvey. — Dame Marie, *17826;* Bayeux, *17994*.

RHODOMELACEAE

Acanthophora muscoides (Linnaeus) Bory. — Jérémie, *17866;* Trou Cochon, *17925*.

Acanthophora spicifera (Vahl) Børgesen. — Dame Marie, *17830;* Léogane, *17963;* Bayeux, *17991*.

Amansia multifida Lamouroux. — Trou Cochon, *17914;* Les Roseaux, *17938*.

Bostrychia Binderi Harvey. — Trou Cochon, *17919* (det. C. K. Tseng).

Bryothamnion Seaforthii (Turner) Kützing. — Dame Marie, *17825;* Trou Cochon, *17921*.

Bryothamnion triquetrum (Gmelin) Howe. — Trou Cochon, *17925;* Les Roseaux, *17944;* Bayeux, *17980*.

Digenia simplex (Wulfen) C. Agardh. — Jérémie, *17895*.

Heterosiphonia Wurdemanni (Bailey) Falkenberg. — Dame Marie, *17820.*

Laurencia obtusa (Hudson) Lamouroux. — Bayeux, *17971.*

Laurencia papillosa (Forsskål) Greville. — Dame Marie, *17849;* Jérémie, *17901;* Saint Louis du Sud, *17951;* Bayeux, *17981.*

Lophosiphonia obscura (C. Agardh) Falkenberg. — Trou Cochon, *17904.*

Polysiphonia ferulacea Suhr. — Trou Cochon, *17915.*

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PLATES I–IV

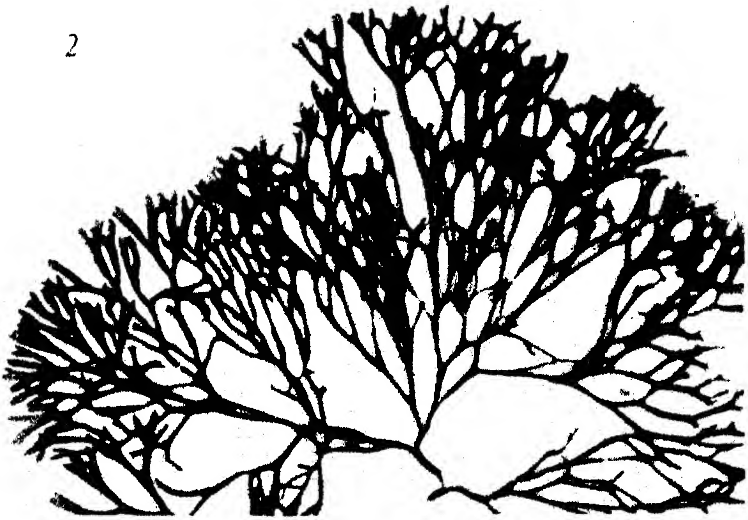


Fig. 1. *Gelidiella trinitatensis*, sp. nov. × 10
Fig. 2. *Gloiophlaea caribaea*, sp. nov. × 2

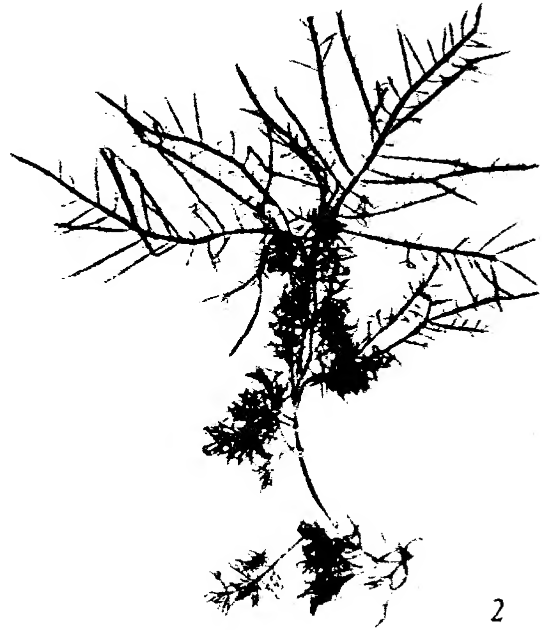
1

2

Fig. 1. *Gelidium crinale* (Turner) Lamouroux var. *platycladum*, var. nov., tetrasporic. × 1.2

Fig. 2. *Pterocladia capillacea* (Gmelin) Bornet & Flahault. × 0.9 (from specimens in the Herbarium of the New York Botanical Garden)

1



2

FIG. 1. *Gelidium floridanum*, sp. nov., cystocarpic. × 0.9
FIG. 2. *Gelidium floridanum*, sp. nov., tetrasporic. × 0.9
(From specimens in the Herbarium of the New York Botanical Garden)

1

2

Fig. 1. *Pterocladia americana*, sp. nov. × 1.2 (from a specimen in the Herbarium of the New York Botanical Garden)

Fig. 2. *Pterocladia Bartlettii*, sp. nov. × 0.8

MARINE ALGAE OF HONG KONG. III

THE GENUS BOSTRYCHIA *

CHENG KWEI TSENG

BOSTRYCHIA Montagne (1842) is a genus of small algae generally at least partly dorsiventral and decumbent. The frond is filamentous, mostly distichously, sometimes quite irregularly, branched, and often with inrolled apices. The filament is subcylindrical or compressed, polysiphonous, consisting of a central siphon surrounded by several rows of pericentral cells which may be naked (ecorticate) or covered with from one to several layers of smaller rectangular cells (corticate), which thus form a somewhat parenchymatous cortex. After being divided vertically from the central siphon cell, the pericentral cell so produced always divides again, by means of a horizontal wall, to form two cells. Therefore it results that there are two pericentral cells to each central siphon cell; in other words, the central cells are twice as long as the pericentral. In some species, however, one or both of the pericentral cells formed by the horizontal division divide once or twice more, thus producing from three to six pericentral cells in each central one. The behavior in this respect seems to be invariable in each particular species, which warrants its application in the classification of the genus. The number of rows of pericentral cells, on the contrary, is not constant, varying from five to ten in the lower part of the thallus and gradually decreasing upward until the ultimate ramuli, or at least their apical portions, are more or less monosiphonous. Members of this genus generally bear, besides the primary holdfasts, a number of accessory attaching organs, the haptera. These are either "cladohaptera," modified branches or branchlets occurring at regular and definite positions, or "peripherohaptera," proliferations from the pericentral cells issuing irregularly anywhere, mainly at or near the point of the branching. Tetrasporangia are tetrahedrally divided and

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are found in swollen fusiform terminal stichidia in a double row. Cystocarps are terminal on the branchlets, generally ovate, with distinct apical ostioles. Spermatangia are formed on the swollen ends of the ultimate branchlets.

Members of this genus are generally dull blackish or livid purple. They inhabit salt marshes, mangrove swamps, and brackish waters at the estuaries of rivers and streams, or even truly fresh waters far away from the seas, and grow on mud-covered rocks or the stems and roots of mangroves and other seed-bearing plants in the littoral region, or sometimes even far above high-water mark, where they are reached only by occasional splashes of waves. They prefer sheltered places and are sometimes found inside caves, pendent from the roofs, where it is dim and dark.

In describing the genus Bostrychia, Montagne (1842, p. 39) cites two species: *Rhodomela scorpioides* Ag. and *R. calamistrata* Mont. The type of the first species came from Selsey, England, and was originally described as *Fucus scorpioides* Gmel.; that of the second species came from Cuba, in the West Indies. Since the genus was published in a book dealing with the natural history of Cuba, it would seem that what Montagne had in mind as the type of the genus was *Rhodomela calamistrata* Mont. (now regarded as synonymous with *Bostrychia tenella* (Vahl) J. Ag.), which he himself described a few years earlier, rather than the English species. A great many species have been added to Montagne's genus since its publication, and up to quite recently over forty were recognized and accepted by contemporary phycologists. In 1936 Miss Post published a thorough revision of the whole genus and, having studied all the type or authentic specimens (except one type specimen which could not be located and is regarded as lost) of these species, came to the conclusion that only eleven were to be accepted as valid and either reduced the rest to synonymy or placed them in the status of varieties or forms in the accepted species. She also published at that time a manuscript species of Grunow and a new species of her own. In 1939 she issued another new one. An additional species is described in the present article, making a total of fifteen species known to date.

The naming and classification of members of this genus had for a long time been a difficult matter because of the wide distribution of most of the species and, consequently, their great variability. In her recent revision Post was able to clear up the whole situation,

after having studied, as mentioned above, the type or authentic specimens of the various proposed species as well as a great abundance of new material from diverse parts of the world. Determination of species of Bostrychia is now a much easier task. Briefly, the important characteristics are: the nature of the haptera, the cortication of the thallus, the presence or absence of the long and the dwarf shoots as well as of the normal monosiphonous branchlets, and the relative lengths of the central siphon and the pericentral cells.

Two species of Bostrychia have previously been reported from the Hong Kong region, namely, *B. Binderi* Harv. (Post, 1936, p. 31) and *B. tenella* (Vahl) J. Ag. (Post, 1937, p. 12). Both records were based on the present writer's collections, the first on specimens from Cheungchau (*Tseng 228*) and Stanley Bay (*Tseng 626, 678*) and the second on material found sparsely intermingled with the *B. Binderi* from Cheungchau (*Tseng 228a*). So far as the entire China coast is concerned, *B. Binderi* has also been recorded from Tonghu, Swatow (*Tseng 549*), and Tsingyu, Haitan I., Fukien (*Tseng 1784*), and *B. tenella* has been recorded from Kwannan, Wenchang, Hainan (*Tseng 757*). Another species, *B. kelanensis* Grun., was later reported from Seaotan, Amoy (Post, 1939, p. 154), the record being based on *Tseng 2575a*, which contained material of the species mixed up with Caloglossa.

The writer and his helper have recently assembled ten more collections, besides several fragments of these plants intermingled with various other algae, from the Hong Kong region. A detailed study of these materials shows the presence of five more species, including a new one (see p. 171). The following analytic key serves to distinguish the species now found to occur in this region:

A. Haptera modified branchlets (cladohaptera), issuing regularly
- *B*. Frond without a special short trunklike axis; two pericentral cells longitudinally to each central siphon cell; pericentral cells elongate-rectangular, longer than broad . . . . 1. *B. radicans*, p. 168
- *B*. Frond with a special short but well-developed trunklike axis; three pericentral cells longitudinally to each central siphon cell; pericentral cells quadrate to subquadrate, generally shorter than broad 2. *B. kelanensis*, p. 169

A. Haptera not modified branchlets (peripherohaptera), issuing irregularly
- *B*. Frond ecorticate, delicate
  - *C*. Two pericentral cells longitudinally to each central siphon cell
    - *D*. Frond with regular monosiphonous ramuli and more abundant branching; filaments large, to 150 μ in diameter 3. *B. hongkongensis*, p. 171

D. Frond without monosiphonous ramuli and showing rather scanty branching; filaments smaller, to 90 μ in diameter
4. *B. simpliciuscula*, p. 173

C. From four to six pericentral cells longitudinally to each central siphon cell .... 5. *B. intricata*, p. 174

B. Frond corticated, robust

C. Ultimate ramuli with abundant regular truly monosiphonous filaments, 24–30 μ in diameter .... 6. *B. tenella*, p. 176

C. Ultimate ramuli polysiphonous throughout or with a few irregular proliferated monosiphonous filaments, 15–18 μ in diameter
7. *B. Binderi*, p. 177

1. *Bostrychia radicans* (Mont.) Mont.

(Plate I, Figures 1–3)

In Kützing, Species algarum, 1849, p. 839, Tabulae phycologicae, XV, 1865, pl. 20, figs. a–c; Montagne, Cryptogamia Guyanensis, 1850, p. 286; J. Agardh, Species . . . algarum, II (3), 1863, p. 856; Falkenberg, Rhodomelaceen, 1901, p. 513, pl. 12, fig. 4; De Toni, Sylloge algarum, IV (3), 1903, p. 1156; Post, Notizen, 1936, p. 13; Børgesen, *Catenella Nipae* Used as Food, 1938, p. 267, fig. 3.

Rhodomela radicans Montagne, Plantes cellulaires, II, 1840, p. 198, pl. 5, fig. 3.

Bostrychia Leprieurii Montagne, Cryptogamia Guyanensis, 1850, p. 287; J. Agardh, *loc. cit.;* Kützing, Tabulae phycologicae, XV, 1865, pl. 23, figs. a–c; De Toni, *op. cit.*, p. 1150.

Polysiphonia spinescens Montagne, Cryptogamia Guyanensis, 1850, p. 289.

Bostrychia rivularis Harvey, Nereis Boreali-Americana, II, 1853, p. 57, pl. 14 D; J. Agardh, *op. cit.*, p. 955; Kützing, Tabulae phycologicae, XV, 1865, pl. 22, figs. d–g; Falkenberg, *op. cit.*, p. 514, pl. 14, fig. 18; De Toni, *op. cit.*, p. 1157.

Polysiphonia bostrychiodes Montagne, Plantes cellulaires, VIII, 1859, p. 175.

Bostrychia glomerata J. Agardh, *op. cit.*, p. 859; De Toni, *op. cit.*, p. 1152.

B. bipinnata Harvey ex J. Agardh, *op. cit.*, p. 860.

B. polysiphonioides Crouan, in Schramm et Mazé, Algues de la Guadeloupe, 1865, p. 25.

B. guadelupensis Crouan, in Schramm et Mazé, *op. cit.*, p. 26; De Toni, *op. cit.*, p. 1169.

B. fulcrata Zanardini, Phycearum Indicarum, 1872, p. 136, pl. 4 A, figs. 1–5; De Toni, *op. cit.*, p. 1149.

Frond dull purplish violet, diffuse, tufted, about 1.5 cm. high, composed of well-developed, irregularly branched, flexuous creeping stoloniferous filaments from which the erect branches are evolved. Numerous strong discoid holdfasts emitted by the stout reflexed filaments. Erect branches distichously branched, rather sparsely and irregularly pinnately decompound (see Pl. I, Fig. 1). Main axis somewhat flexuous. Branches largest in the middle, up to 240 μ in diameter, tapering toward both extremities, sometimes, for instance, measuring 90 μ in the lower basal portion, gradually increasing to 170 μ in the middle and then decreasing again to 90 μ at the apical part.

Filaments ecorticate and polysiphonous throughout. Pericentral cells elongate-rectangular in surface view, about 1.5–2.0 times longer than broad; in longitudinal view two to each central siphon cell (see Pl. I, Fig. 2); in transverse section various in number, from eight to six in the main branches, decreasing to four in the branchlets. Ultimate branchlets all more or less incurved. Accessory attachment organs of the cladohapteron type, consisting at the ends of bundles of rhizoids, regularly developed from the basal branchlets of the branches (see Pl. I, Fig. 3). Tetrasporangia developed from the terminal branchlets.

Habitat. — On littoral mud-covered rocks in sheltered mangrove swamp: Shatin, Tide Cove, in May (*Tseng 2790a*) associated with *Bostrychia kelanensis*); Aberdeen, Hong Kong I., in July (*Taam 152c*, chiefly associated with *Caloglossa Leprieurii*).

Distribution. — Sinnamary, French Guiana, northern South America (type locality); widely distributed in tropical and subtropical waters.

The Hong Kong plants, according to the description above, belong to f. *depauperata* Post.

2. *Bostrychia kelanensis* Grun.

(Plate II, Figures 1–5)

In Post, Notizen, 1936, p. 20.

Frond purplish violet, attached by a stout broad discoid holdfast, with a characteristically stout thick "trunk" as much as 0.4 mm. in diameter and 0.8 mm. high, which is several times thicker than the main branches that arise from it distichously when young (see Pl. II, Fig. 1) and spirally when older. One or more of the main branches extending horizontally to serve as stolons and at some distance from the mother plant fixing themselves on the substratum and each producing a trunklike axis, from which branches issue similarly. Repetition of this process resulting in a diffuse loose tuft, each individual, however, being distinct because of the presence of the trunk. Main branches regularly and repeatedly subdichotomously branched in one plane. Mature and better-developed fronds generally quite regularly decompound-subpinnate, with a strongly flexuous axis. Branches about 150 μ in diameter near the trunk and gradually becoming smaller until about 60 μ in diameter near the apices. Ac-

cessory attachment organs of the cladohapteron type, bearing rhizoidal filaments at the apices of the branches. Filaments ecorticate, polysiphonous throughout and distinctly articulate. Articulations very short, generally from 2.5 to 3.0 times shorter than broad. Pericentral cells nearly quadrate or shorter than broad, varying from eight in the lower part to four near the apices (see Pl. II, Fig. 2), three longitudinally to each central siphon cell (see Pl. II, Fig. 3). Tetrasporangial stichidia fusiform, much swollen, terminal at the branches, about 180 μ broad and 0.60–0.72 mm. long (see Pl. II, Fig. 4). Tetrasporangia about 60 μ in diameter.

f. **elegans,** f. nov.

Planta a forma typica differt frondibus alterne copiose decomposito-subpinnatis, ramulis ultimis plerumque apice in haptera transformatis.

Specimen typicum: *Taam A152a* (in herbario auctoris), ad rupes argillosas litoreas prope Aberdeen, Hong Kong I., 16 Jul., 1941.

Habitat. — On trunks and roots of mangroves in the littoral region, Shatin, Tide Cove, in April (*Tseng 2756*). On sheltered mud-covered littoral rocks in mangrove swamp: Shatin, Kowloon, in April (*Tseng 2727b*, associated mainly with Caloglossa) and May (*Tseng 2787a*, associated mainly with Catenella, and *Tseng 2790*); Aberdeen, Hong Kong I., in April (*Tseng 2702*) and July (*Tseng 2575e* and *Taam A152a*, TYPE of f. *elegans*, both associated chiefly with Caloglossa).

Distribution. — Kelana, New Zealand (type locality of the species); Amoy, China; widely distributed in the Indo-Pacific regions.

In the original description *Bostrychia kelanensis* Grun. is characterized by "inferne irregulariter et subfasciculatim ramosis, ramis subsimplicibus vel parce divisis . . . ." It is evident, therefore, that the type belongs to the *depauperata* form, with irregular and very few branches, corresponding to the forms *genuina* of *B. simpliciuscula*, *inermis* of *B. intricata*, and so on. This original form of Grunow's the writer proposes to call f. **typica,** nom. nov. The Hong Kong plant, f. *elegans*, on the other hand, is regularly and quite richly branched, and, when fully developed, forms haptera at the ends of most branchlets (see Pl. II, Fig. 5), thus corresponding to what Post calls f. *hapteromanica* of *B. radicans*.

The present species is certainly very distinctive and can be easily recognized by the following characteristics: the presence of an erect stout thick trunklike axis, the cladohapteron type of accessory holdfast, the very short articulations, with quadrate to subquadrate pericentral cells, and the one-to-three ratio of the length of the pericentral cells to that of the central siphon cell. The last characteristic is especially outstanding, the only other species credited with a similar ratio being *Bostrychia tangatensis* Post (1939, p. 152). The latter species, however, has an entirely different kind of haptera, the peripheral type, and lacks the characteristic trunklike axis of the present species. *B. kelanensis* is usually found intermingled with *B. intricata*, which also has short pericentral cells. That species differs from this one distinctly in having peripherohaptera and from four to six pericentral cells longitudinally to each central siphon cell, in lacking the trunklike axis, and in the parenchymatous appearance of the nonarticulated filaments in surface view. At first the writer was rather suspicious that the difference between the three and the four–six pericentral cells longitudinally to each central cell might be a mere matter of the stage of development. A study of numerous specimens revealed, however, that this ratio is quite constant, even in very young portions. Besides, though both species have short pericentral cells, those of *B. kelanensis* are generally squarish, whereas those of *B. intricata* are much shorter, usually half as high as broad. The present species is, moreover, a much more delicate plant.

3. **Bostrychia hongkongensis**, sp. nov.

(Plate III)

Frons rubropurpurea, ca. 20 mm. alta, caespitosa, diffusa, intricata, aut omnino alterne distiche decomposito-pinnata aut inferne subfurcata, superne subpinnata, articulata, ecorticata; ramis principalibus usque ad 150 μ latis, polysiphoniis cellulis pericentralibus instructis; cellulis pericentralibus sterilibus in segmenta duo transversaliter subdivisis, i.e. cellulis axilibus quam pericentralibus duplo longioribus; ramulis ultimis cum pinnulis monosiphoniis alternis instructis; fulcris flagelliformibus irregulariter dispositis prope rachidem orientibus. Stichidia, cystocarpia, et spermatangia ignota.

Specimen typicum: *Tseng 2716* (in herbario auctoris), ad rupes argillosas litoreas prope Saiwan, Hong Kong I., 11 Apr., 1940. Duplicum in Herb. Univ. Mich.

Frond reddish purple, intricately caespitose, up to 20 mm. high. Branching alternate, distichous, irregularly subpinnately decompound, sometimes subfurcate below (see Pl. III, Fig. 1). Filaments articulate and ecorticate throughout. Main branches as much as 150 μ in diameter, polysiphonous, each consisting of a central siphon surrounded generally by six pericentral cells which decrease upward to four. Pericentral cells in surface view elongate-rectangular, generally about twice as long as broad, two longitudinally to each central cell (see Pl. III, Figs. 3–4). Articulations usually slightly shorter than the diameter. Ultimate branchlet consisting of a polysiphonous base with a few simple or slightly branched, subcorymbosely disposed, monosiphonous filaments (Pl. III, Figs. 3–4). Cells of these filaments rectangular, a little longer than broad, slightly constricted at the transverse walls, about 45 μ in diameter in the lower part, decreasing gradually to about 30 μ in diameter at the tips. Haptera of the peripheral type, issuing irregularly, frequently occurring, however, at or near the points where branching takes place, formed by proliferations from the pericentral cells (see Pl. III, Fig. 2). All materials collected were sterile.

Habitat. — Forming intricate mass on sheltered littoral mud-covered rocks, Saiwan, Hong Kong I., in April (*Tseng 2716*, TYPE; *Tseng 2712a*, intermingled with *Bostrychia tenella* and *B. simpliciuscula*). On sandy loam in mangrove swamp at high-tide mark, Taipa I., Macao, in April (*Tseng 2720*).

The present species is characterized by the distinctly articulate ecorticate frond with longitudinally elongated pericentral cells, of which there are two to each central cell, by peripherohaptera, and by regular, normal, monosiphonous ramuli. Its nearest relative is undoubtedly *Bostrychia simpliciuscula* Harv. (= *B. tenuis* Post), which is sometimes found intermixed in the same tuft and which differs from the present species in the absence of monosiphonous filaments, the thallus being polysiphonous throughout. *B. simpliciuscula* is much slenderer, also, being generally only half as broad as the present species. The relationship between the two is somewhat similar to that between *B. tenella* and *B. Binderi*, as well as to that between *B. Moritziana* and *B. radicans*. The profusely branched ecorticate frond with monosiphonous branchlets in the present species reminds one very much of *B. Moritziana;* the latter species, however, has the cladohapteron type of accessory holdfast and a more robust

frond, with more abundant monosiphonous filaments. In the combinations of characteristics of specific value by Post (1939, p. 153) the present species belongs to the hypothetical species No. 3.

4. *Bostrychia simpliciuscula* Harv. ex J. Ag.

(Plate II, Figures 6–7)

J. Agardh, Species . . . algarum, II (3), 1863, p. 854; Falkenberg, Rhodomelaceen, 1901, p. 512; De Toni, Sylloge algarum, IV (3), 1903, p. 1155; Harvey, Friendly Islands Algae no. 23 (nomen subnudum).

Bostrychia rivularis Harvey, Phycologia Australica, III, 1860, pl. 176 B (non *B. rivularis* Harvey, Nereis Boreali-Americana, II, 1853, p. 57, pl. 14 D).

B. Andoi Okamura, Icones of Japanese Algae, I (5), 1907, p. 102, pl. 22, figs. 14–22.

B. tenuis Post, Notizen, 1936, p. 22.

Frond intricate, rather scantily and irregularly branched, with branches of the neighboring orders differing only slightly in diameter (see Pl. II, Fig. 6). Branches about 60–90 μ in diameter near the base, very gradually attenuated upward to 30–40 μ in diameter at the tips, generally about 55–65 μ in diameter for the larger part of the frond. Filaments ecorticate and polysiphonous throughout except in the tips, where they may remain monosiphonous for a short distance. Pericentral cells generally in four rows in the erect branches and in five or six rows in the creeping ones, two longitudinally to each central siphon cell, in surface view about 1.2–1.5 times longer than broad. Peripherohaptera issuing irregularly and giving rise to elongate rhizoidal filaments about 18–20 μ in diameter (see Pl. II, Fig. 7). Plants reddish purple.

Habitat. — On littoral muddy rocks in sheltered salt marsh: Saiwan, Hong Kong I., in April (*Tseng 2712a*, associated mainly with *Bostrychia tenella*, but also with *B. hongkongensis*); Shatin, Tide Cove, in July (*Taam A146a*, associated with *B. Binderi*).

Distribution. — Friendly Is. (type locality), East Africa, Riukiu Is., Australia, New Zealand, Chile.

From the synonyms listed above, it is clear that Post is not justified in proposing the new name *Bostrychia tenuis* merely because the two earlier valid names, *B. simpliciuscula* and *B. Andoi*, do not refer to the "typical" form of the species. Whether the form represented by "*B. rivularis*" Harv. from Australia (1860) or that represented by *B. simpliciuscula* and *B. Andoi* is typical is subject to differences of opinion, and technically, nomenclaturally, the two

latter names have priority so far as the species itself is concerned. The name *B. simpliciuscula* Harv. ex J. Ag. should therefore be used for this particular species, and it follows, in a technical sense, which may or may not agree with the true natural state, that the irregularly and sparsely branched form *is* the *typical* form, for which the writer proposes the form name f. **genuina,** nom. nov. (= *B. tenuis* Post, f. *simpliciuscula* (J. Ag.) Post), based on Harvey's Friendly Islands Algae no. 23. Accordingly, for the form with abundant regular distichous branches the form name f. **luxurians,** nom. nov., is proposed, based on "*B. rivularis*" Harv. (1860, pl. 176 B), which is *B. tenuis* Post f. *typica* Post.

The present species is closely related to *Bostrychia hongkongensis* Tseng, as was mentioned under that species. They resemble each other in the ecorticate frond with similarly shaped pericentral cells, in the ratio between the length of these cells and that of the central siphon cells, and in the kind of haptera. *B. simpliciuscula* differs, however, from *B. hongkongensis* in the absence of truly monosiphonous filaments, in the scanty irregular branching, with the branches of the various orders more equal in diameter, and in the much thinner filaments. On the basis of these conspicuous differences the two species, although sometimes occurring in the same tuft, can readily be distinguished from each other.

5. *Bostrychia intricata* (Bory) Mont.

(Plate I, Figures 4–5)

Montagne, Diagnoses phycologicae, 1852, p. 317; J. Agardh, Species . . . algarum, II (3), 1863, p. 866; Kützing, Tabulae phycologicae, XV, 1865, p. 23, figs. d–f; De Toni, Sylloge algarum, IV (3), 1903, p. 1166.

Scytosiphon intricatum Bory, in Dumont d'Urville, Flore des Malouines, 1826, no. 8 bis (nomen nudum).

Scytonema intricata Bory, Cryptogamie, in Duperrey, Voyage autour du monde, 1829, p. 225.

Bostrychia Hookeri Harvey, in Hooker f. and Harvey, Algae Antarcticae, 1845, p. 269; Harvey, Nereis Australis, 1847, p. 69; Kützing, Species algarum, 1849, p. 840, Tabulae phycologicae, XV, 1865, pl. 21, figs. a–c; J. Agardh, *op. cit.*, p. 857; Falkenberg, Rhodomelaceen, 1901, p. 509, pl. 11, figs. 19–24; De Toni, *op. cit.*, p. 1148.

B. fastigiata Harvey, in Hooker f. and Harvey, *loc. cit.;* Harvey, *loc. cit.;* Kützing, Species algarum, 1849, p. 840; J. Agardh, *op. cit.*, p. 857; De Toni, *op. cit.*, p. 1151.

B. mixta Hooker f. et Harvey, *op. cit.*, p. 270; Harvey, *op. cit.*, p. 70, Phycologia Australica, III, 1860, pl. 176 A; Kützing, Species algarum, 1849, p. 840, Tabulae phycologicae, XV, 1865, pl. 20, figs. d–f; J. Agardh, *op. cit.*, p. 858;

Falkenberg, *op. cit.*, p. 511; De Toni, *op. cit.*, p. 1150; Post, Notisen, 1936, p. 39.
B. Laingii J. Agardh, Analecta algologica, IV, 1897, p. 72; De Toni, *op. cit.*, p. 1151.

Frond about 12 mm. high, sparingly, distantly, and subdichotomously branched (see Pl. I, Fig. 4). Branches up to 240 μ in diameter in the lower portions, attenuated upward to 40–60 μ in diameter at the apices. Terminal segments subulate, more or less incurved. Filaments ecorticate, polysiphonous, and inarticulate throughout. Pericentral cells in surface view subquadrate to almost hexagonal, about one third to one half shorter than broad; from four to six longitudinally to each central siphon cell (see Pl. I, Fig. 5). Haptera of the peripheral type, formed at irregular intervals (see Pl. I, Fig. 4). Tetrasporangial stichidia terminal and much swollen.

Habitat. — Intermingled with various mangrove-swamp algae on mud-covered littoral rocks: Saiwan, in April (*Tseng 2712f*, with *Bostrychia tenella* and other algae), and Aberdeen, in July (*Tseng 2575a* and *Taam A152b*, both associated with *Caloglossa Leprieurii*), both on Hong Kong I.; Taipa I., Macao, in April (*Tseng 2719b*, with *C. Leprieurii*, and *Tseng 2720a*, with *B. hongkongensis*).

Distribution. — Falklands Is., subantarctic South America (type locality); widely distributed in the subantarctic regions and in the warmer seas.

This is a very common alga in the mangrove swamps of this region. So far, however, it has never been found in the pure condition or as the dominant element of a tuft or a patch. Instead, it always occurs intermingled, as a minor constituent, with other algae. The Hong Kong plant, as seen from the description above, belongs to f. **inermis** (Post), comb. nov. (*Bostrychia mixta* f. *inermis* Post).

In discussing the right specific epithet to apply to the present species Post (1936, p. 39) selected *Bostrychia mixta* Hook. f. et Harv., presumably on the basis of priority. A little checking of the synonyms listed above, however, shows clearly that there were three valid names published ahead of *B. mixta*. The specific epithet *intricata* first appeared in Dumont d'Urville's *Flore des Malouines* (1826), in the name "*Scytosiphon intricatum* Bory"; since there is no accompanying description, this must be regarded as a *nomen nudum*. Three years later Bory validly published the same plants under *Scytonema intricatum*. Bory based his species on two specimens;

of these, according to Post, who has studied both, the Falklands specimen belongs here, whereas the Chilean specimen is referred to *B. scorpioides* Mont. Post (1936, p. 36) in the list of synonyms of the latter species makes this remark: "*Scytonema intricata.* 'Chili,' leg. D.-J. Durville, Herb. Rostoc. (d. Typus von den Falklands ist dagegen *B. mixta!*)." To be sure, Bory did not designate either of the two specimens as the type. Nevertheless, since he was the one who named the Falklands plant *Scytosiphon intricatum* in d'Urville's *Flore des Malouines*, since this was the first plant mentioned in his *Scytonema intricatum*, and since the descriptions both of Bory and of Montagne, who transferred it to Bostrychia, apply better to the present species, it is clear that the specific name *intricata* must be applied to the Falkland specimen, not to the Chilean. Post, also, regards the former as the type of *Scytonema intricatum* Bory. It follows, therefore, that the correct name to apply to this plant is *B. intricata* (Bory) Mont.

Even if it can be proved that the specific epithet *intricata* cannot be used for this species, there are still two other valid names, *Bostrychia Hookeri* Harv. and *B. fastigiata* Harv. These, together with *B. mixta* Hook. f. et Harv., are all published in the same paper, but they have priority of place (one page ahead) and thus invalidate the last name. Post mentioned another synonym also, *Fucus exilis* of R. Brown, 1801, which is evidently a manuscript name, for it is not found in any of the standard works, such as Turner's *Fuci* and the treatises of C. Agardh, J. Agardh, Kützing, and De Toni.

6. *Bostrychia tenella* (Vahl) J. Ag.

(Plate I, Figure 6)

J. Agardh, Species . . . algarum, II (3), 1863, p. 869; Falkenberg, Rhodomelaceen, 1901, p. 515, pl. 12, figs. 10–13; De Toni, Sylloge algarum, IV (3), 1903, p. 1162; Okamura, Icones of Japanese Algae, I (5), 1907, p. 96, pl. 22, figs. 1–13; Howe, Algae, in Britton, Flora of Bermuda, 1918, p. 523; Børgesen, Marine Algae of the Danish West Indies, II, 1920, p. 300; Post, Notizen, 1936, p. 25.

Fucus tenellus Vahl, Kryptogamiske Planter fra St. Croix, 1802, p. 45.

Rhodomela calamistrata Montagne, Plantes cellulaires, 1837, p. 354.

Bostrychia calamistrata (Mont.) Montagne, Plantes cellulaires . . . Cuba, 1842, p. 39, pl. 4, fig. 1 a–g; Kützing, Species algarum, 1849, p. 839, Tabulae phycologicae, XV, 1865, pl. 19, figs. a–c; Harvey, Nereis Boreali-Americana, II, 1853, p. 56, pl. 14 C.

B. elegans Crouan, in Schramm et Mazé, Algues de la Guadeloupe, 1865, p. 25.

B. muscoides Crouan, *loc. cit.*

B. pilifera Kützing, Tabulae phycologicae, XV, 1865, pl. 25, figs. d–f.

Frond forming extensive prostrate intricate patches, with its branches overlapping each other, dorsiventral, distichously pinnately decompound. Main axis about 2–3 cm. long, twice or thrice pinnately branched. Branches either elongated and indefinite (long shoots) or short and definite (dwarf shoots). Ultimate branchlets terminating in simple or branched monosiphonous filaments which may consist of as many as 40 cells. These cells slightly barrel-shaped, about 24–30 μ in diameter and longer than broad, slightly broader below, attenuated toward the apices (see Pl. I, Fig. 6). Main axis, principal branches, and thicker branchlets all corticated, the corticating cells 30–45 μ in diameter. Pericentral cells in transverse section from six to seven, giving rise to the few layers of cortical cells; in longitudinal section two to each central siphon cell. Periphero-haptera issuing irregularly. Tetrasporangial stichidia cylindrical-rostrate to lanceolate, up to 150 μ in diameter and 800 μ long. Plants brownish purple and rather soft.

Habitat. — Pendent on the roof of a cavern, high above the highest water mark, Cheungchau, in October (*Tseng 228a*, associated with *Bostrychia Binderi*). On sheltered mud-covered littoral rocks: Aberdeen, in April (*Tseng 2705a*, associated with Boodleopsis), and Saiwan, in April (*Tseng 2712*), both on Hong Kong I.; Clear Water Bay, Port Shelter, in March (*Tseng 2683*).

Distribution. — St. Croix, West Indies (type locality); Hong Kong and Hainan, China; widely distributed in tropical and subtropical waters.

7. *Bostrychia Binderi* Harv.

(Plate I, Figures 7–8)

Harvey, Nereis Australis, 1847, p. 68, pl. 28; J. Agardh, Species . . . algarum, II (3), 1863, p. 873; Falkenberg, Rhodomelaceen, 1901, p. 521; De Toni, Sylloge algarum, IV (3), 1903, p. 1166; Post, Notizen, 1936, p. 28.

Bostrychia sertularia Montagne, Plantes cellulaires, VIII, 1859, p. 176; Howe, Algae, in Britton, Flora of Bermuda, 1918, p. 523.

B. tenella var. *terrestris* J. Agardh, *op. cit.*, p. 869.

B. Vieillardi Kützing, Tabulae phycologicae, XV, 1865, p. 10, pl. 26, figs. a–e.

B. Mazei Crouan, in Schramm et Mazé, Algues de la Guadeloupe, 1865, p. 26.

B. capillacea Crouan, in Mazé et Schramm, Algues de la Guadeloupe, 2d ed., 1877, p. 254.

Amphibia pectinata (Kütz.) Howe, Algae, in Britton and Millspaugh, Bahama Flora, 1920, p. 573.

Frond forming densely crowded extensive prostrate intricate mats, with its branches overlapping each other, dorsiventral, distichously

pinnately decompound, with both long and dwarf shoots and irregularly disposed peripheral haptera. Ultimate branchlets typically short, spinelike, and polysiphonous throughout, sometimes, under certain environmental conditions, proliferating shorter or longer monosiphonous filaments, which generally consist of only a few cells, but occasionally of as many as twenty-five. These filaments to some extent superficially simulating the truly monosiphonous branchlets of the previous species, but always confined to the last order of the branching system, or to only a part of it, and having then a polysiphonous base (see Pl. I, Fig. 8); cylindrical throughout, without any sign of constriction; cells small, about 15–18 μ in diameter and about as long as broad; sometimes colorless in the terminal part, resembling very much the rhizoidal filaments issuing from the haptera. Branches of all orders corticated and polysiphonous throughout except in the monosiphonous proliferations mentioned above. Corticating cells about 15–20 μ in diameter. Pericentral cells from six to seven in transverse section, two longitudinally to each axial siphon cell. Tetrasporangial stichidia varying in shape from ovoid and shortly cylindrical-clavate to elongate-cylindrical-rostrate, about 150–180 μ in diameter and from two to five times as long. Apex obtuse, acute, or apiculate, or even with a branchlet above (see Pl. I, Fig. 7). Plants generally violet or brownish purple.

Habitat. — (1) The shade plants: Cape d'Aguilar, in March (*Tseng 2686*), and Stanley Bay, in June (*Tseng 2650*), both on Hong Kong I.; Clear Water Bay, Port Shelter, in May (*Tseng 2804*); Cheungchau, in October (*Tseng 228*, with *Bostrychia tenella* as a minor constituent of the patch). (2) The light plants: Stanley Bay, in March (*Tseng 626, 678*), and Aberdeen, in April (*Tseng 2705b*, associated with Boodleopsis and *Bostrychia tenella*), both on Hong Kong I.; Shatin, Tide Cove, in May (*Tseng 2793*) and July (*Taam A146*); Clear Water Bay, Port Shelter, in March (*Tseng 2683a*, associated with *Bostrychia tenella*).

Distribution. — Port Natal (type locality); Hong Kong, Swatow, and Hainan, China; widely distributed in tropical and warmer seas.

The plants collected in the Hong Kong region all come near to f. *typica* Post. They can, however, be further separated into two groups, as has been done under "Habitat" above, depending upon the amount of light they receive. One group, as represented by *Tseng 228*, include slenderer and softer plants found pendent on the roofs

of caverns very far above high-tide mark, where they received very little light. These have been called "shade plants," and they are usually violet purple. They used to be called *Bostrychia sertularia* Mont., which is now regarded as a synonym of the present species. The other group, as represented by *Tseng 626*, have a much more robust and rigid frond and occur on muddy rocks in the littoral region, where they are exposed to strong light. These have been called "light plants," and are usually brownish purple. They were formerly known as *Amphibia pectinata* (Kütz.) Howe, which is also now synonymous with *B. Binderi*. Both forms are found in sheltered places; the writer has never collected any where the current is strong and the rocks exposed and clean.

The present species and *Bostrychia tenella* certainly resemble each other very much in several characteristics. Consequently, there has been a controversy as to whether they should be kept separate or should be united into one species, one being made a variety, or even a form, of the other. Howe (1918, 1920) was probably the first to study critically the differences between these two groups. He tried to distinguish them on the basis of (1) the number and relative length of the monosiphonous cells, (2) the shape and relative length of the stichidia, and (3) the color of the frond. With regard to the number of monosiphonous filaments, although it is true that *B. tenella* has many more cells than *B. Binderi*, this factor, if taken alone, is too arbitrary, and not always reliable. In fact, this difference has been too much emphasized and forms the center of the controversy. Again, the relative length of these filaments, whether longer than broad, or vice versa, is also not always constant in each species. That the monosiphonous cells of *B. tenella* are longer than those of *B. Binderi* is quite true, but this is due to the fact that *B. tenella* has larger cells, 25–30 μ in diameter, whereas those of *B. Binderi* are only 15–18 μ in diameter. With regard to the stichidia, they are more constant in shape and comparatively long in *B. tenella* and very variable and comparatively short in the present species. Moreover, those of the former species are always terminal, whereas those of the latter may be terminal and subterminal, since the apical portion often grows into a branch again. As for the color of the frond, it varies according to external conditions and so is certainly not a good criterion specifically.

Quite recently Post (1938) discussed the differences between these

two species, emphasizing (1) the difference between primary and secondary monosiphony, and (2) the occurrence of both species in the same tuft. The writer, also, has studied many living collections of these species and is in perfect agreement with Post. It is clear from an evolutionary and ecological point of view that there must be two species rather than one and a variety since both plants grow in the same tuft and hence under exactly the same ecological conditions; the belief that one is an ecological form or geographical variety of the other is, therefore, without foundation. As regards the monosiphony, what Post takes as "primary" is what the writer would call "true" monosiphony, which occurs regularly, whatever the ecological conditions, and which is typical of *Bostrychia tenella*. The present species, however, has only "secondary" monosiphony, which is irregular and is what the writer would regard merely as "proliferation"; it is formed only under certain ecological conditions, for instance, under the stimulus of very muddy and unfavorable situations. These proliferated monosiphonous filaments not uncommonly have the upper parts irregularly curled and more or less decolorized, so that they resemble very much the rhizoidal filaments issuing from the haptera.

Besides the differences brought to light by Howe and Post, it may be remarked that *Bostrychia tenella* has larger and more or less barrel-shaped monosiphonous cells and larger cortical cells. With all these differences on hand, there can be no further difficulty in distinguishing one species from the other. The following table summarizes the characteristics discussed above:

TABLE I

Comparison of Bostrychia tenella and B. Binderi

	B. tenella	*B. Binderi*
Monosiphony	Primary or true, natural	Secondary or proliferated, ecological
Monosiphonous cells	More or less constricted at transverse wall, all colored, 24–30 μ in diameter	Cylindrical throughout, terminal ones sometimes colorless, 15–18 μ in diameter
Cortical cells	35–40 μ in diameter	15–20 μ in diameter
Stichidia	More regularly shaped, always terminal, from four to ten times longer than broad	Variously shaped, terminal or subterminal, from two to five times longer than broad

SUMMARY

Seven species of Bostrychia, including one new one, have been found in the Hong Kong region. *B. hongkongensis*, sp. nov., is closely related to *B. simpliciuscula* Harv. ex J. Ag., differing in the presence of monosiphonous filaments, in the larger diameter, and in the more regular and abundant branching. *B. radicans* (Mont.) Mont., *B. simpliciuscula* Harv. ex J. Ag., and *B. intricata* (Bory) Mont. are here recorded for the first time for this region as well as for China as a whole. *B. kelanensis* has previously been reported from Amoy and is now added to the flora of Hong Kong. *B. tenella* and *B. Binderi* were already known to occur in this region; a critical comparative study has been made of these two closely related and long-disputed species to determine the fundamental and important differences between them.

The writer wishes to thank Professor Wm. Randolph Taylor, of the University of Michigan, for his advice in preparing the present study.

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EXPLANATION OF PLATE I

FIG. 1. *Bostrychia radicans* (Mont.) Mont. f. *depauperata* Post. Habit sketch of a tetrasporic plant. × 10

FIG. 2. *B. radicans* (Mont.) Mont. f. *depauperata* Post. Lengthwise section of a filament, showing pericentral and axial siphon cells. × 142

FIG. 3. *B. radicans* (Mont.) Mont. f. *depauperata* Post. Upper part of a branch, showing haptera. × 20

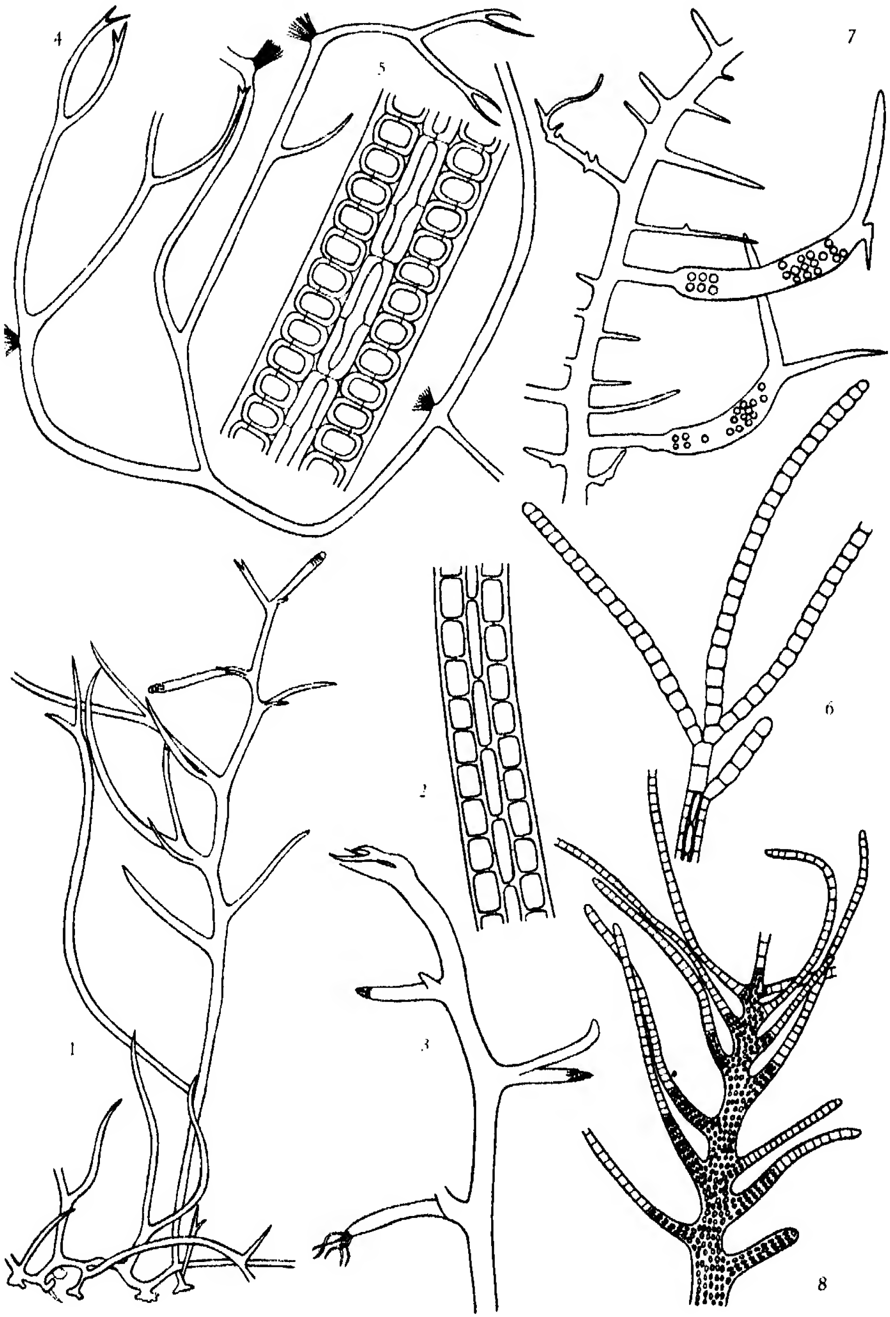
FIG. 4. *B. intricata* (Bory) Mont. f. *inermis* (Post) Tseng. Habit sketch of part of a frond, showing branching and haptera. × 10

FIG. 5. *B. intricata* (Bory) Mont. f. *inermis* (Post) Tseng. Lengthwise section of a filament, showing pericentral and axial siphon cells. × 142

FIG. 6. *B. tenella* (Vahl) J. Ag. Branchlet, showing monosiphonous filaments. × 71

FIG. 7. *B. Binderi* Harv. Part of a frond, showing branching and tetrasporangial stichidia. × 20

FIG. 8. *B. Binderi* Harv. Upper part of a frond, showing branching and proliferated monosiphonous filaments. × 71



Marine algae of the genus Bostrychia

EXPLANATION OF PLATE II

FIG. 1. *Bostrychia kelanensis* Grun. f. *elegans*, f. nov. Habit sketch of a young plant. × 10

FIG. 2. *B. kelanensis* Grun. f. *elegans*, f. nov. Transverse section of a filament. × 68

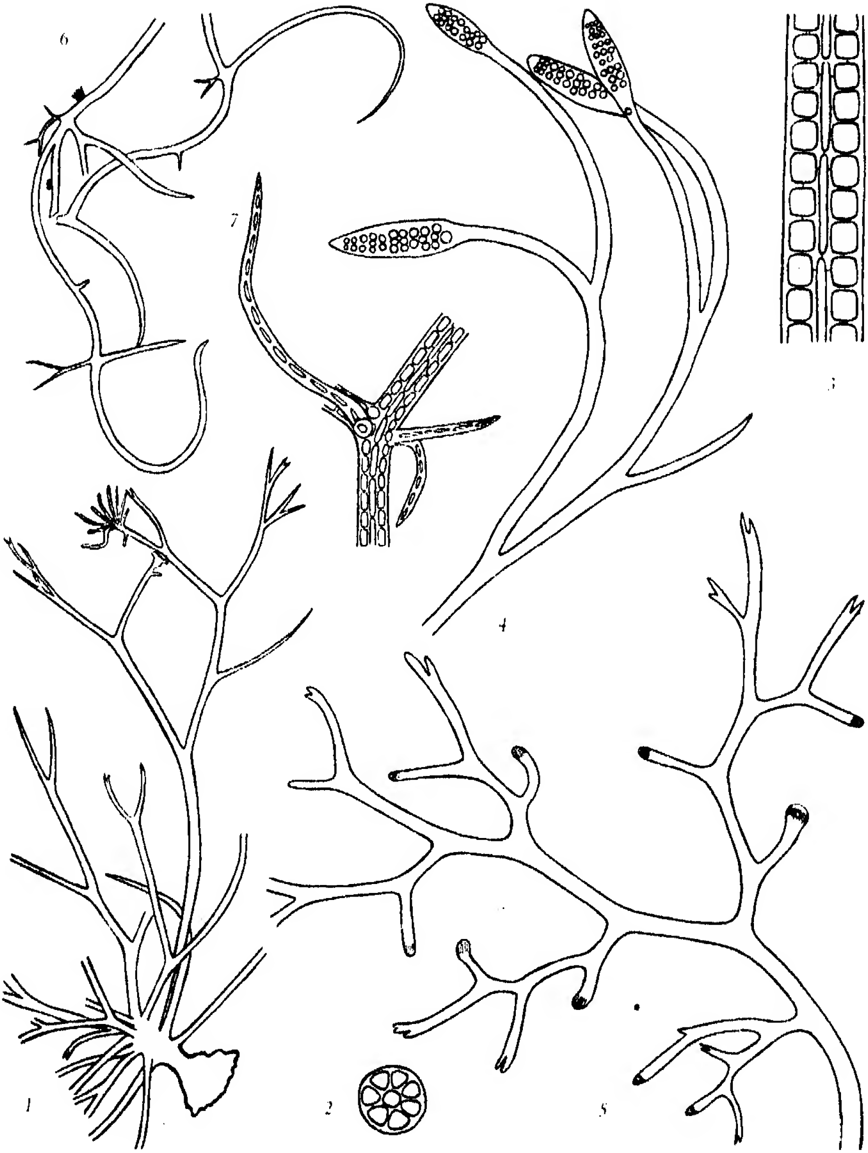
FIG. 3. *B. kelanensis* Grun. f. *elegans*, f. nov. Lengthwise section of a filament, showing pericentral and axial siphon cells. × 136

FIG. 4. *B. kelanensis* Grun. f. *elegans*, f. nov. Upper part of a tetrasporic plant, showing stichidia and sporangia. × 20

FIG. 5. *B. kelanensis* Grun. f. *elegans*, f. nov. Upper part of a mature plant, showing haptera. × 20

FIG. 6. *B. simpliciuscula* Harv. ex J. Ag. Habit sketch of part of a frond, showing branching and haptera. × 15

FIG. 7. *B. simpliciuscula* Harv. ex J. Ag. Lengthwise section of a filament, showing pericentral and axial siphon cells and rhizoidal filaments. × 68



Marine algae of the genus Bostrychia

EXPLANATION OF PLATE III

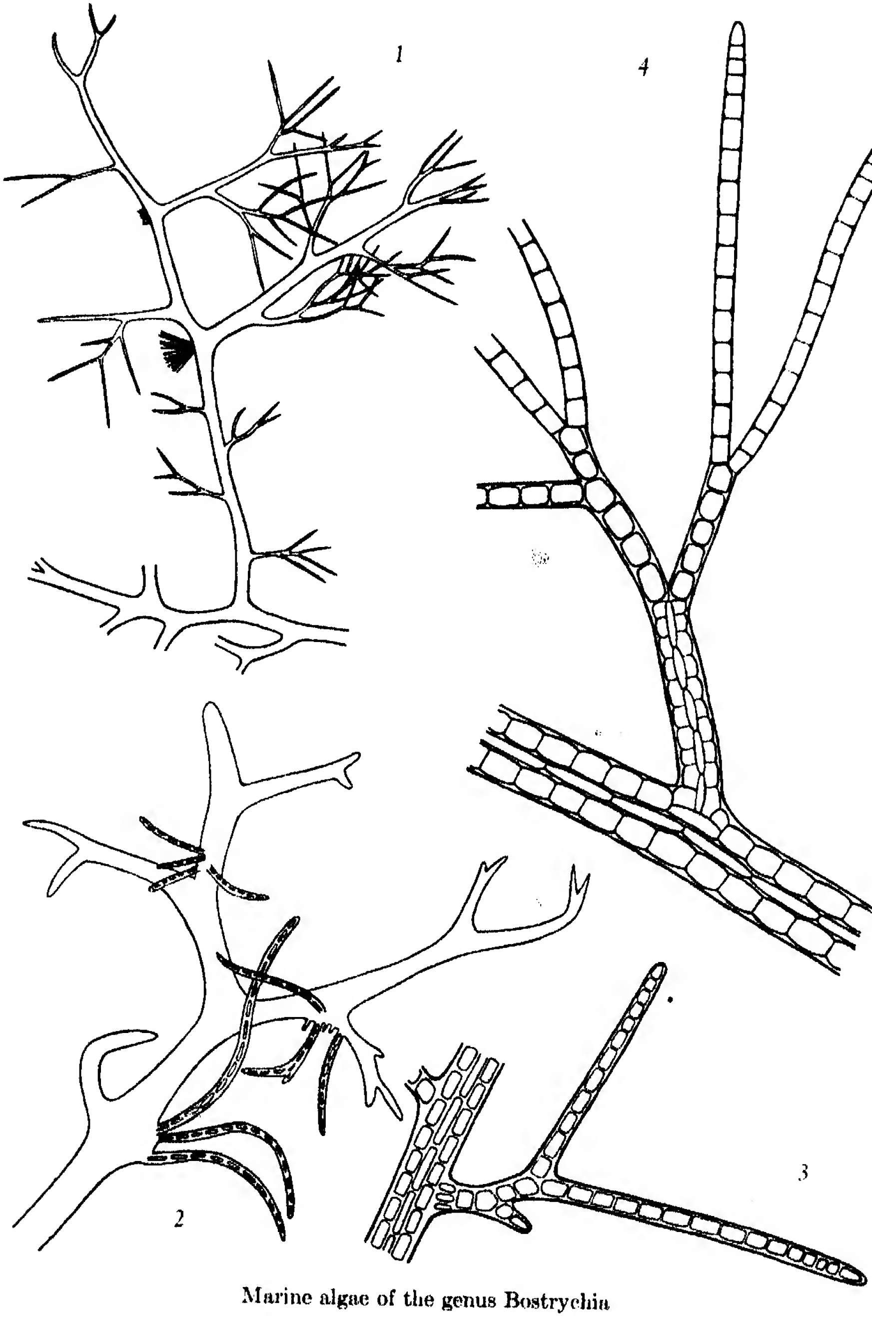
Bostrychia hongkongensis, sp. nov.

FIG. 1. Habit sketch of part of the plant, showing branching. × 12

FIG. 2. Part of the plant, showing rhizoidal haptera. × 89

FIG. 3. Lengthwise sectional view of part of a young branch, showing the pericentral and axial siphon cells and monosiphonous filament. × 89

FIG. 4. Lengthwise sectional view of part of an older branch, showing a monosiphonous branchlet. × 89



Marine algae of the genus Bostrychia

MARINE ALGAE OF HONG KONG. IV
THE GENUS LAURENCIA *

CHENG KWEI TSENG

THE genus Laurencia is a group of generally medium-sized, firmly fleshy or cartilaginous, variously colored "red" algae of tropical and the warmer temperate waters. The fronds are erect and repeatedly pinnately or paniculately branched, sometimes subdichotomous, with terete or compressed branches. They are radially organized, with each axis composed of an axial siphon surrounded by from four to six rows of pericentral cells, which give rise to a rather thick compact parenchymatous cortex with a layer of surface cells. The axis, though fundamentally polysiphonous in structure, is obscure, being visible only at the apices of the branches. As a result, the axial cells and the cortical cells are not clearly distinct from each other and are together generally called the "medulla." The "medullary" cells, in some species, have characteristic refringent lenticular thickenings of the walls. The surface cells, which may well be called "epidermal" cells, are usually hexagonal, but sometimes irregularly polygonal, in surface view. In certain species they are radially elongated and arranged more or less like the palisade cells in transverse sections of the branchlet. In others they are subquadrate or broader than long, not radially elongated nor arranged like palisade cells. The apices of the branches or branchlets are obtuse and crateriform, with apical cells which have three cutting surfaces and which are deeply sunken in the pits and protected by the trichoblasts. The tetrasporangia are tetrahedrally divided, occurring near the apices or scattered in the upper parts of ordinary branchlets or of somewhat modified stichidious ones, which may be simple or branched. They are embedded in the cortical layers and do not originate directly from the pericentral cells. The spermatangial clusters are ovoid to

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subcylindrical, often closely paniculately united and frequently sunken in the greatly enlarged and cup-shaped apical craters. The cystocarps are ovoid, subglobular, or somewhat urceolate, solitary or several crowded together, sessile on the outer surfaces of the upper ultimate branchlets.

Members of this genus are extensively distributed in warmer waters, especially in the tropics. They inhabit both shallow and deep waters, and are found in quiet sheltered spots as well as surf-beaten exposed ones. Generally they prefer places where the current is rapid and the water comparatively clear. They abound especially in tide pools, and are found on rocks, stones, or coral chips.

Most of the species are firmly fleshy to quite cartilaginous; relatively few are soft and tender. Although, compared with other members of the red seaweeds, they are usually erect medium-sized plants, some are very small and inconspicuous, creeping, and intricate, whereas others may reach a height of 30 or more centimeters. They vary a great deal in color, shading from brilliant pinkish red to dull blackish purple. Among members of the same species, however, the color is relatively constant. Some of them, especially those living in shallow waters, appear greenish to bluish.

Lamouroux (1813, p. 130), in founding the genus Laurencia, enumerated eight species, without designating any of them as the type, which is in accord with the practice of early authors. Since *L. pinnatifida* (Gmel.) Lamx., based on *Fucus pinnatifidus* Gmel. from the British Isles and France, was the first name listed, it might reasonably be considered the technical type of the genus. Schmitz and Falkenberg, however, preferred to regard the more widely distributed *L. obtusa* (Huds.) Lamx., based on *Fucus obtusus* Hudson from England, as the type. Since the publication of the genus some scores of species have been added to it. Critical systematic studies have been made by J. G. Agardh (1863, 1876) and, quite recently, by Yamada (1931). Agardh divided the genus into four sections, namely, Filiformes, Papillosae, Obtusae, and Pinnatifidae, differentiating them chiefly by the branching of the fronds and on the basis of whether these were terete or compressed. He listed thirty-eight accepted species and several "*species inquirendae.*" The Agardhian system was adopted by De Toni (1903), who accepted forty-four species, listed sixteen questionable ones, and excluded ten. In his revision of the genus Yamada emphasized the anatomical characters, es-

pecially the transverse-section view of the epidermal cells (surface cells), whether radially elongated and palisade-like or not, and the presence or absence of lenticular thickenings on the medullary cell walls. He redivided the genus, retaining but emending the section Pinnatifidae, discarding the three remaining sections suggested by J. Agardh, and proposing three other sections, namely, Palisadae, Forsterianae, and Cartilagineae. Sixty-four species were listed, including fifteen new ones, and many former species were reduced to the status of varieties or synonyms of the accepted species. Yamada had examined most of the type or authentic specimens in the various important American and European herbaria, and the results of his studies of these specimens were incorporated in the revision, making it a most valuable one. Unfortunately for phycologists who have not had access to these type specimens, the author did not publish enough details (especially microscopic characters and measurements, as well as details concerning the structure of reproductive organs) to give them a sufficiently clear and definite idea about many of the species or to clarify his interpretation of them. Some published species and varieties and some specimens distributed in important exsiccatae were also disregarded, which makes their status questionable. "*Laurencia paniculata*" (no. 21 of Okamura's *Algae Japonicae Exsiccatae*), for instance, which is apparently not that species but probably near to *L. glandulifera* Kütz., was not dealt with at all.

Since the appearance of Yamada's revision twelve more species have been published by various authors (Yamada, one; Børgesen, three; Howe, two; Howe and Taylor, one; and Setchell and Gardner, five), bringing the total number of accepted species to seventy-six. In general the taxonomy of the genus is now based mainly on such external morphological characters as the branching of the frond, the terete or compressed state of the branches, and the tetrasporiferous branchlets, and on the internal anatomy.

No Laurencia species has hitherto been reported from the Hong Kong region. From other parts of the China coast the following six are already known: *L. obtusa* (Huds.) Lamx. and *L. venusta* Yam. from Peitaiho, *L. capituliformis* Yam. from Tengchoufou, *L. intermedia* Yam. from Tengchoufou and Tsingtao, *L. Okamurai* Yam. from Peitaiho and Amoy, and *L. papillosa* (Forssk.) Grev. from Tsingtao and Amoy. It is to be noted that the records of "*L. papillosa*" are probably erroneous, at least those reported by the present

writer; but since the specimens on which these records were based are not available now, it is not possible to correct the identifications at this time. In the past few years the writer and his assistants have assembled about 150 different collections of Laurencia from the various parts of the China coast. Of these, about one third came from the Hong Kong region. Although it is the author's intention to report his study of all of these collections in the near future, the twelve species from the Hong Kong area will be discussed in this paper first, for they represent very interesting plants, eight of which have not hitherto been described. The fact that these new species are mostly small and inconspicuous probably explains why they have not been reported previously. The writer would not be surprised if they should eventually be found to be common in the nearby regions, especially those bordering the South China Sea. The following key serves to distinguish the Hong Kong Laurenciae from each other:

A. Frond simple or furcate .... 10. *L. subsimplex*, p. 202
A. Frond repeatedly and profusely branched
  B. Frond with branches decidedly compressed and distichous except near tips and base
    C. Frond small, as much as 4 cm. high and 2 mm. broad, cartilaginous; epidermal cells projecting near ends of branchlets; margin of fertile branches not undulate ..... 11. *L. parvipapillata*, p. 204
    C. Frond larger, as much as 7 cm. high and 4 mm. broad, fleshy; epidermal cells not projecting; margin of fertile branches undulate .... 12. *L. undulata*, p. 206
  B. Frond with branches generally cylindrical or slightly compressed and polystichous
    C. Epidermal cells elongated radially, arranged like palisade cells in transverse section of branchlets
      D. Branches crowded near apex, with subflabellately cymose or irregularly digitate closely set branchlets more or less in two ranks .... 4. *L. longicaulis*, p. 194
      D. Branches more loosely and evenly disposed, with irregularly set branchlets in more than two ranks
        E. Ultimate branchlets turbinate, strongly swollen at tips, crowded on minor branches .... 1. *L. jejuna*, p. 189
        E. Ultimate branchlets subcylindrical or subclavate, more loosely disposed on minor branches
          F. Ultimate branchlets longer, up to 3 mm. or more in length, lower ones several times longer than upper ones .... 3. *L. surculigera*, p. 192
          F. Ultimate branchlets very short, about 1 mm. long, all of approximately the same length 2. *L. paniculata*, p. 191
    C. Epidermal cells neither elongated radially nor arranged like palisade cells in transverse section of branchlets

D. Frond small, about 1.0 cm. high and 0.5 mm. in diameter, very soft and slender, repeatedly subflabellately dichotomous or subdichotomous; tetrasporangia on ultimate segments of all branches and branchlets .... 9. *L. tenera*, p. 200

D. Frond larger, 2.5 cm. or more high, 1 mm. or more in diameter, firmer and more robust, pinnately branched; tetrasporangia only on ultimate branchlets

E. Frond a beautiful pinkish red; epidermal cells projecting more or less at ends of branchlets; medullary cell walls without lenticular thickenings 8. *L. obtusa* var. *majuscula*, p. 200

E. Frond brownish red to dark purple; epidermal cells not projecting; medullary cell walls with lenticular thickenings

F. Frond small, about 2.5 cm. high or less, sparsely branched, articulate here and there 5. *L. articulata*, p. 195

F. Frond large, 8–30 cm. high, profusely branched, not articulate

G. Main axis slightly compressed; principal branches issuing from all sides; branches densely covered with ultimate branchlets ..... 6. *L. japonica*, p. 197

G. Main axis strongly compressed; principal branches apparently distichous; branches covered loosely with ultimate branchlets .... 7. *L. chinensis*, p. 198

1. **Laurencia jejuna**, sp. nov.

(Plate I, Figures 1–3)

Frons fuscopurpurea, ca. 3 cm. alta, substantia firma, dense caespitosa, discis ad saxum adfixa; ramis principalibus teretibus, usque ad 1.1 mm. diam., e trunco brevi orientibus, erectis vel aliquando arcuatis, inferne plerumque annulose articulatis, subnudis, mox laxe alternate vel opposite subpinnate decompositis; ramulis ultimis distichis vel tristichis, juventate subcylindricis, aetate clavatis vel turbinatis, ad apicem capitatis vel tuberculosis, fertilibus simplicibus ad apicem valde inflatis vel lobatis, aut a verrucis multis (2–5) irregulariter tectis; in sectione transversali cellulis epidermalibus plus minusve valliformibus, radialiter elongatis, 15–20 μ latis, 20–35 μ altis; cellularum medullosarum parietibus incrassationibus lenticularibus aut annularibus saepe instructis; tetrasporangiis sphaericis, ca. 120 μ diam., in ramulorum ultimorum apicibus sitis; cystocarpiis urceolatis, usque ad 0.9 mm. latis, 1.3 mm. longis, in ramulo sessilibus. Acervuli spermatangiales ignoti. Species *Laurenciae papillosae* (Forssk.) Grev. proxima videtur.

Specimen typicum: *Tseng 2565* (in herbario auctoris), ad rupes zonae inferioris litoralis, prope Shek-O, Hong Kong I., 15 Jul., 1937.

Frond tufted, about 3 cm. high, attached by a discoid holdfast, dark purple, firmly subcartilaginous. Principal branches arising from a well-developed short thickish trunk, terete, up to 1.1 mm. in diameter, erect or sometimes arcuate, often annulate-articulate and sparsely branched below, loosely alternately or oppositely subpinnately decompound above (see Pl. I, Fig. 1). Ultimate branchlets distichous or tristichous, subcylindrical when young and clavate to turbinate with capitate or tuberculate apices when older; when fertile, either simple and greatly inflated or lobed at the apices, or irregularly covered with from two to five warts, which are rounded at the tips and attenuated at the bases (see Pl. I, Fig. 1). Epidermal cells in transverse section of the branchlets palisade-like, radially elongated, about 15–20 μ broad and 20–35 μ high, with thick walls (see Pl. I, Fig. 3). Medullary cells with very thick walls, often with lenticular, arcuate, or annulate thickenings. Tetrasporangia spherical, up to 120 μ in diameter, situated at the much-swollen apices of the ultimate branchlets, which may be simple or give rise to from two to five warts, thus becoming more or less compound. Cystocarps urceolate, as much as 0.9 mm. broad and 1.3 mm. long, including a neck about 0.2–0.3 mm. long, generally solitary and sessile on the minor branches, together with one or two sterile branchlets (see Pl. I, Fig. 2). Spermatangia not found.

Habitat. — On littoral rocks and in rock pools: Repulse Bay, in May (*Tseng 2799*), Big Wave Bay, in June (*Tseng 2852*), and Shek-O, in July (*Tseng 2565*, TYPE), all on Hong Kong I.; Potaiau, Kowloon, in July (*Taam A142*).

The inclusion of *Tseng 2799* in this species is made with some reservation. It is a slightly larger plant (to 4 cm. high and 1.3 mm. in diameter, is more profusely branched than the type collection, and has no articulation. Otherwise it agrees quite well with the species.

This new species is undoubtedly closely related to the presumably widely distributed *Laurencia papillosa* (Forssk.) Grev., originally described from the Red Sea, but now reported from almost everywhere in tropical and subtropical waters. The differences are chiefly in the disposition of the branchlets, which in the Red Sea plant are densely crowded and from four- to many-ranked; in the anatomy

of the frond, which in that species has very strongly radially elongated epidermal cells and medullary cell walls without any lenticular thickenings; and in the disposition of the cystocarps, many of which are crowded on the same branchlet in *L. papillosa.* The latter species is also noted for its rigid thallus, almost coriaceous when dried, and its often greenish to yellowish purple color, which is not true of *L. jejuna.* As its name indicates, the Hong Kong species is a diminutive plant, reaching full maturity, with both sexual and asexual organs, when only 3 cm. high. Its annular articulations and sometimes arcuate branches with unilaterally disposed branchlets, well exhibited in the type collection, also help to characterize this species.

2. *Laurencia paniculata* (C. Ag.) J. Ag.

J. Agardh, Species . . . algarum, II (3), 1863, p. 755, III, 1876, p. 651; De Toni, Sylloge algarum, IV (3), 1903, p. 788; Yamada, Notes on Laurencia, 1931, p. 192, pl. 3, fig. a; Børgesen, Marine Algae . . . Iranian Gulf, 1939, p. 119, fig. 33.

Chondria obtusa var. *paniculata* C. Agardh, Species algarum, I (2), 1822, p. 343.
Laurencia thuyoides Kützing, Tabulae phycologicae, XV, 1865, pl. 74, figs. a–b.

Frond tufted, attached by discoid holdfasts, about 5 cm. high, irregularly paniculately decompound. Branches of all orders terete, up to 1.8 mm. in diameter, subfastigiate below and more divaricate above, the primary ones up to 2.5 cm. long. Ultimate branchlets generally shortly clavate, sometimes turbinate or wartlike, about 1 mm. long, issuing in various directions on the minor branches. Epidermal cells angularly subrotund in surface view and more or less palisade-like in transverse section, 15–30 μ broad and 25–45 μ high; more elongated radially and more distinctly palisade-like, from two to three times longer than broad in sections near the apices, and broader, about from one and one half to two times higher than broad, in sections lower down in the branchlets; subquadrate, almost as broad as high, in sections of the branches and main axis. Medullary cell walls very much thickened, sometimes with what appear to be lenticular thickenings, which are, however, not refringent. Tetrasporangia about 90 μ in diameter when mature, situated very near the apices of the ultimate branchlets, often in rather regular rings. Fertile branchlets simple toward the apices of the minor branches and somewhat branched lower down, as are the sterile ones. Young cystocarps urceolate, sessile on much-shortened branchlets, in groups of from two to five, issuing in all directions. Spermatangia not found. Plants

firm and subcartilaginous, dull reddish purple when living, turning grayish purple when dried.

Habitat. — On littoral rocks and in rock pools between tide marks: Shek-O, Hong Kong I., from April to May (*Tseng 2562*, *Taam A92*); Lunghawan, Port Shelter, in May (*Tseng 2580*); Pakpai I., near Putoi I., in May (*Taam A112*); Lamma I., in May (*Taam A120*).

Distribution. — Adriatic Sea (type region), Mediterranean Sea, Iranian Gulf, New Caledonia.

The writer is not entirely without hesitation in identifying the Hong Kong plants with the Adriatic species. They agree quite well with the description by J. Agardh and the photograph of the type specimen published by Yamada (1931). They do not resemble, however, the "*Laurencia paniculata*" of the American phycologists — for instance, Phycotheca-Boreali-Americana, no. 1093, and specimens identified with it by Farlow, Collins, and others. Though Yamada (*loc. cit.*) made known the characteristics of the type specimen, he did not, unfortunately for phycologists, clear up the status of these various specimens, currently known under this supposedly cosmopolitan species, or that of the Japanese specimen which appears under the same name (Okamura's Exsiccata no. 21). They seem to be heterogeneous, representing several species rather than a single one. It is very necessary, to understand the Agardhian species more definitely, that a detailed description of the macroscopic and microscopic characteristics as well as of the reproductive organs be prepared, based on the type specimen and supplementary topotype materials. The range of variation should be similarly determined. Until this information is available the writer has to be content with his present identification of the Hong Kong specimens and has to interpret *L. paniculata* rather vaguely, as a member of the section Palisadae with a firmly subcartilaginous frond, more or less paniculate branching, and very short, but rather loosely disposed, ultimate branchlets.

3. **Laurencia surculigera,** sp. nov.

(Plate I, Figures 4–5)

Frons fulvopurpurea, ca. 4.5 cm. alta, molliter carnosa, e surculis basi prostratis assurgens; surculis teretibus, discis membranaceis latis vel rhizoideis ad substratum adfixis; ramis erectis teretibus

vel leviter compressis, subpinnate decompositis, percurrentibus, usque ad 2 mm. latis, in parte media modice crassioribus quam in basi et apice attenuatis; ramulis ultimis subcylindricis vel clavatis, apice truncatis vel rotundis, usque ad 3 mm. longis, quoquoversum egredientibus, plerumque longitudine intervalla aequantibus; cellulis epidermalibus a superficie visis angulate subrotundis, parietibus tenuibus, in sectione transversali valliformibus, radialiter elongatis, 15–30 μ latis, 30–45 μ altis; cellularum medullosarum parietibus partes incrassatas lenticulatas non ostendentibus; partes aliae desunt. Species *Laurenciae perforatae* (Bory) Mont. et *L. palisadae* Yam. proxima videtur.

Specimen typicum: *Tseng 293* (in herbario auctoris), ad rupes litorales, prope Stanley Bay, Hong Kong I., 11 Apr., 1933.

Frond brownish purple, about 4.5 cm. high, softly fleshy, arising from prostrate terete surculi and attached by broadly membranaceous discoid holdfasts or by bundles or rhizoids. Erect branches terete or slightly compressed, subpinnately decompound, percurrent, up to 2 mm. broad, broadest in the middle part and attenuated more near the base and less near the tips. Primary branches, while still young, sometimes curving down toward the substratum, fixing by means of secondary holdfasts and acting as surculi, with further branching taking place secundly and dorsally (see Pl. I, Fig. 4). Ultimate branchlets subcylindrical to clavate, truncate or rounded at the apices, up to 3 mm. long, emerging in various directions although usually appearing distichous in dried specimens, mostly separated from each other by spaces subequal to their own length. Epidermal cells angulate-rounded or somewhat hexagonal, with rather thin walls in surface view, palisade-like, evidently radially elongated, 15–30 μ broad and 30–45 μ high in transverse section of the branchlets (see Pl. I, Fig. 5). Medullary cells without lenticular thickenings of the walls. All specimens collected were sterile.

Habitat. — On littoral rocks and in rock pools in rather sheltered places: Stanley Bay, Hong Kong I., in April (*Tseng 293*, TYPE); Putoi I., in April (*Tseng 2747*).

This new species is a member of the section Palisadae, closely related to *Laurencia perforata* (Bory) Mont. from the Canary Islands, on the one hand, and to *L. palisada* Yam. from Formosa, on the other. It resembles the Canary Islands alga in the presence of the curved branches and secund branchlets, which, however, occur

much more frequently in the latter species. *L. perforata* is, moreover, a much smaller plant, with rather scanty branching and more predominantly decumbent habit. The disposition of the ultimate branchlets in *L. surculigera* is similar to that in *L. palisada*, which, however, has a distinct thickish stem from which several primary branches arise. In addition, the Formosan species does not appear to have surculi. The present species differs from *L. paniculata* J. Ag. in the softly fleshy substance, the much simpler, looser, sometimes secund branching, and the presence of surculi. It must be remembered, however, that this species is founded on sterile specimens. Its actual relationship with other species can be known only when fruiting material is available.

4. **Laurencia longicaulis,** sp. nov.

(Plate II, Figures 1–2)

Frons fulvopurpurea, ca. 4.5 cm. alta, firmiter carnosa, caespitosa, discis ad saxum adfixa; ramis principalibus teretibus, usque ad 2 mm. diam., numerosis, a trunco brevi ca. 1 mm. alto orientibus, inferne longe subnudis, subsimplicibus, aliquando annulose articulatis, superne dense alternatim ramosis; ramulis ultimis clavatis, 0.50–0.65 mm. diam., pseudopolychotomose vel cymose fasciculatis, ad apicem truncatis; in sectione transversali cellulis epidermalibus evidenter radialiter elongatis, 15–18 μ latis, 30–36 μ altis, simili modo ut cellulis valliformibus dispositis; cellularum medullosarum parietibus incrassationibus lenticularibus aut annularibus saepe instructis; tetrasporangiis sphaericis, usque ad 90 μ diam., in superiore parte ramorum ramulorumque ortis. Cystocarpia et acervuli spermatangiales ignota. Species *Laurenciae flagelliferae* J. Ag. proxima videtur.

Specimen typicum: *Tseng 2579* (in herbario auctoris), ad rupes litoreas, prope Big Wave Bay, Hong Kong I., 20 Mai., 1938.

Frond yellowish purple, firmly fleshy, about 4.5 cm. high, caespitose, attached by a broad discoid holdfast and with a well-developed short thickish trunk about 1 mm. high, from which several main filaments arise. These filaments subcylindrical, attenuated below and broadening above to 2 mm. in diameter; usually with annular scars; naked and unbranched (or with only a few short branchlets below) for a distance of 15–30 cm., closely set above, near the apices, with secondary branches, which arise alternately and more or less

distichously, producing subflabellately cymose or irregularly digitate ultimate branchlets (see Pl. II, Fig. 1). These branchlets clavate and broadly truncate at the apices, about 0.50–0.65 mm. in diameter. Epidermal cells in surface view hexagonal or polygonal, 15–18 μ broad, in transverse section of the branchlets evidently radially elongated and palisade-like, 15–18 μ broad, 30–36 μ high (see Pl. II, Fig. 2). Medullary cells large, very thick walled, often with lenticular, arcuate, or annulate thickenings. Tetrasporangia spherical, up to 90 μ in diameter, scattered near the apices of the branches and branchlets. Sexual organs not found.

Habitat. — On surf-beaten littoral rocks: Big Wave Bay, in May (*Tseng 2579*, TYPE), Shek-O, in May (*Tseng 2625*), both on Hong Kong I.; Potaiau, Kowloon, in May (*Taam A103*).

The present species is certainly a very characteristic one, easily recognized and distinguished from other members of the Palisadae by its fleshy caespitose frond with a short thickish trunk which is naked and unbranched for a long distance below, then more or less densely alternately branched above, with closely set, flabellately cymose or pseudopolychotomous branchlets. It is undoubtedly most closely related to the East Indian *Laurencia flagellifera* J. Ag., which is also a member of the Palisadae and which resembles the present species in some of the characteristics mentioned above. The Indian plant, however, is a much more elegant species, from two to four times higher than the present one; it does not have the special short thickish trunk and has many fewer and much looser branchlets.

5. **Laurencia articulata,** sp. nov.

(Plate II, Figures 3–4)

Frons fuscopurpurea, ca. 2.5 cm. alta, substantia firma, laxe intricata, pro majore parte repens, discis ad saxum adfixa; ramis principalibus numerosis, e trunco brevi usque ad 2.5 mm. crasso orientibus; ramis ramulisque teretibus, 0.4–1.1 mm. latis, irregulariter distincte annulose articulatis, unilateraliter raro alternate vel opposite sparsim ramosis, in parte superiore saepe arcuatis, ad apicem plerumque haptera rhizoidea formantibus; ramulis clavatis, apice truncatis; in sectione transversali cellulis epidermalibus subquadratis, 25–30 μ diam., haud simili modo ut cellulis valliformibus dispositis, parietibus cellularum medullosarum incrassationem lenti-

culatam ostendentibus; tetrasporangiis sparsis, oblongis, usque ad 90 μ latis, 120 μ longis, in ramulis ultimis (qui sunt sterilibus similes) sitis. Cystocarpia et acervuli spermatangiales ignota. Species *Laurenciae pygmaeae* Web.-v. B. proxima videtur.

Specimen typicum: *Tseng 2561* (in herbario auctoris), ad rupes arenosas litoreas, prope Stanley Bay, Hong Kong I., 14 Jul., 1937.

Frond dark purple, firmly subcartilaginous, about 2.5 cm. high; loosely intricate, largely prostrate, attached by a discoid holdfast and with a well-developed short trunk about 2.5 mm. thick, from which several principal branches arise (see Pl. II, Fig. 3). These branches terete, 0.4–1.1 mm. broad, generally broadest in the middle part and more or less attenuated toward both ends. Annular discs found here and there irregularly but quite abundantly, the filaments thus appearing distinctly articulate (see Pl. II, Fig. 3). Branching generally unilateral, sometimes alternate or even opposite. Branches and branchlets often more or less arcuate, curving toward the substratum, upon touching which their apices are often transformed into haptera giving rise to numerous well-developed rhizoids; growth of these branches necessarily becoming definite, and secondary branches arising unilaterally from the dorsal sides. Branches clavate, truncate at the apices. Epidermal cells in transverse section of the branchlets subquadrate, 25–30 μ broad and 25–32 μ high, not radially elongated nor arranged like palisade cells (see Pl. II, Fig. 4). Lenticular thickenings present in the medullary cell walls. Tetrasporangia few, oblong, up to 120 μ long and 80–90 μ broad, developed near the apices of the ultimate branchlets. Sexual organs not found.

Habitat. — On sand-covered littoral rocks, Hong Kong I., in July: Stanley Bay (*Tseng 2561*, TYPE) and Wongmakok, Titam Peninsula (*Taam A148*).

The present species is certainly a very characteristic and easily recognizable one. It is unique in the section Forsterianae in its irregularly scattered cup-shaped annular scars, which make the filaments appear distinctly articulate, and in its arcuate branches often with apical tenaculae and unilateral dorsal branchlets. It is probably more closely related to the Malayan *Laurencia pygmaea* Web.-v. B. than to other members of the section. That species, however, besides not having the unique characteristics mentioned above, is a much smaller plant, only up to 250 μ in diameter. Though annular scars have been reported in *L. flagellifera* J. Ag., *L. longi-*

caulis Tseng, and *L. jejuna* Tseng, all belonging to the section Palisadae, they are by no means so abundant or of such general occurrence in every part of the thallus in these species as in the present one. Curved branches and unilateral branching are found in a few other species, especially *L. perforata* (Bory) Mont., *L. surculigera* Tseng, and, to a lesser extent, *L. jejuna*, all of which belong to the section Palisadae, with comparatively poorly developed repent filaments. As for the presence of apical tenaculae, there seems to be no parallel with it in this genus, so far as the writer's information goes.

6. *Laurencia japonica* Yam.

Yamada, Notes on Laurencia, 1931, p. 211, fig. L, pl. 10, figs. a–b.

Frond dark purple, somewhat subcartilaginous, up to 30 cm. high, caespitose, arising from a densely intricate mass of rhizoidal or stoloniferous filaments, attached by basal discs; repeatedly irregularly pinnately branched, with longer branches below and shorter ones above, thus forming a pyramidal outline. Main axis terete when young and somewhat compressed when older, straight or slightly flexuous, broadest in the middle part, up to about 2.2 mm. in diameter, and attenuated toward both extremities. Primary branches issuing alternately or suboppositely, rather patent and open. Ultimate branchlets shortly clavate, truncate or rounded at the apices, distichous and subopposite when young, sometimes tristichous, subfastigiately and loosely disposed; more densely crowded in older branches, reminding one somewhat of *Laurencia papillosa*. Epidermal cells in transverse section of the branchlets irregularly subquadrate or slightly elongated tangentially, not arranged like palisade cells, about 20–30 μ broad and 28–30 μ high. Tetrasporangia slightly oblong, as much as 130 μ long and 120 μ broad, scattered in the stichidious branchlets, which are pinnately compound when mature. Cystocarps ovate-urceolate, up to 0.72 mm. broad and slightly longer, obliquely sessile, several crowded together on the upper part of the fertile branchlets. Spermatangia not found.

Habitat. — Abundant on rocks near the lower littoral region: White Sand Beach, Stanley, in March (*Tseng 585*), April (*Tseng 295*), and May (*Tseng 322*), Shek-O, in January (*Taam A26*), March (*Tseng 2655, Taam A73, A74*), and May (*Tseng 2626*), Cape d'Aguilar, in March (*Tseng 2697*), Repulse Bay, in May (*Tseng 2800*), Big

Wave Bay, in May (*Taam A120*), all on Hong Kong I.; Lamma I., in May (*Taam A121*); Putoi I., in June (*Tseng 2823*).

Distribution. — Amatsu and Emi, Boshu Province, Japan (type region).

Plants of *Laurencia japonica* Yam. vary a good deal upon aging, as its describer remarked. The species has previously been known only from the type region, and from there only in the original record of its occurrence, although it is, presumably, common in Japan. It is therefore interesting to find it so abundant in the Hong Kong region. It must be noted that the original description allows it a maximum height of only 8 cm., whereas the Hong Kong plants attain a height of 30 cm. In other respects, however, these plants agree well with Yamada's account. The writer, although unable to study the type or any authentic specimen, feels quite confident in making the identification.

7. **Laurencia chinensis**, sp. nov.

(Plate III, Figures 1–3)

Frons rubropurpurea, ca. 8 cm. alta, cartilaginea, e surculis prostratis assurgens; surculis teretibus, tenuibus, ca. 0.2–0.3 mm. latis, rhizoideis robustis saxo adfixis; ramis erectis ad basim teretibus, sursum mox plus minusve distincte compressis, in parte superiore et in ramulis subteretibus, duplo vel triplo pinnatim ramosis; ramis principalibus usque ad 1.2 mm. latis, percurrentibus, juventate distinctis, aetate obscuris, circumscriptione paniculiformibus vel subcorymbiformibus; ramulis ultimis subcylindricis, distichis vel tristichis, ad apicem truncatis; in sectione transversali cellulis epidermalibus subquadratis, 30–45 μ diam., haud simili modo ut cellulis valliformibus dispositis; parietibus cellularum medullosarum incrassationem lenticulatam ostendentibus; tetrasporangiis usque ad 120 μ diam., densis in apicibus ramulorum ultimorum sitis. Cystocarpia et spermatangia ignota. Species *Laurenciae japonicae* Yam. proxima videtur.

Specimen typicum: *Tseng 295a* (in herbario auctoris) ad rupes arenosas zonae inferioris litoralis, prope White Sand Beach, Stanley, Hong Kong I., 15 Apr., 1933.

Frond reddish purple, cartilaginous, up to 8 cm. high. Basal

filaments horizontally creeping, terete, slender, 0.2–0.3 mm. broad, producing rhizoids downward (see Pl. *III*, Fig. 1). Erect filaments abundantly pinnately decompound, terete near the base, becoming more or less distinctly compressed upward, up to 1.2 mm. broad. Main axis percurrent, generally conspicuous, at least when young, and later sometimes more or less obscured by the vigorously growing lateral branches. Outline of the frond pyramidal or corymbose-paniculate. Branches at first distinctly distichous and opposite, later more or less tristichous or polystichous because of further growth of younger branches from the same nodes; the two older, opposite, distichous branches of each node, however, always the best developed, and so causing the branching, even in mature plants, to appear superficially distichous and opposite. Ultimate branchlets subcylindrical, distichously or tristichously disposed, and truncate at the apices. Epidermal cells in transverse section of the branchlets subquadrate, 30–45 μ high and 25–45 μ broad, not radially elongated like palisade cells (see Pl. III, Fig. 2). Medullary cell with lenticular thickenings of the walls. Tetrasporangia spherical, up to 120 μ in diameter, scattered near the apices of the ultimate branchlets, which are generally simple, but sometimes branched (see Pl. III, Fig. 3). Sexual organs not found.

Habitat. — On sand-covered rocks in the lower littoral region: White Sand Beach, Stanley, in April (*Tseng 295a*, TYPE), Big Wave Bay, in March (*Taam A59*) and May (*Tseng 2576*, *Taam A122*), Wongmakok, Titam Peninsula, in May (*Taam A113*), all on Hong Kong I.; Lamma I., in May (*Tseng 2586*).

Among members of the section Forsterianae, to which it most probably belongs, the present species is unique in its distinctly and strongly compressed main axis when mature and its apparently distichous branching. In this respect it resembles members of the Pinnatifidae. The main axis is subcylindrical when young however, and the branching, though distichous at first, becomes polystichous, although quite obscurely, at last. It seems to stand between Forsterianae and Pinnatifidae, probably near *Laurencia japonica*, which is also distichous when young. That species, however, has its ultimate branchlets densely crowded when older, its axis is only very slightly compressed, and its main branches are irregularly and closely disposed.

8. *Laurencia obtusa* (Huds.) Lamx. var. *majuscula* Harv.

Harvey, Phycologia Australica. V, Synoptic Catalogue, 1863, p. xxvi, no. 309b; Yamada, Notes on Laurencia, 1931, p. 223; Børgesen, Some Indian Rhodophyceae, III, 1933, p. 135.

Frond a beautiful pinkish red, robust but soft, up to 20 cm. high, quite regularly pinnately decompound, with a percurrent axis which is straight or slightly flexuous, terete, and about 2 mm. in diameter. Branches alternate or subopposite, spirally inserted, patent, diminishing in length from base to apex, thus giving the frond a pyramidal outline. Ultimate branchlets short, clavate, obtuse at tips, and subopposite. Epidermal cells in surface view irregularly oval or subrotund, 40–60 μ in diameter, more or less projecting near the ends of the branchlets; in transverse sections irregularly subquadrate, not radially elongated like palisade cells. Medullary cells without lenticular thickenings of the walls. Tetrasporangia about 120 μ in diameter, dispersed in simple or branched subcylindrical ultimate branchlets. Cystocarps ovate-urceolate, about 1 mm. broad and slightly shorter, solitary and sessile on ultimate branchlets. Spermatangia not found.

Habitat. — On rocks in the lower littoral region or, more commonly, drifted ashore: Big Wave Bay, in May (*Tseng 2760*), and Saiwan, in June (*Tseng 2844*), both on Hong Kong I.; Panglongwan, in March (*Taam A63*), and Lunghawan, in May (*Taam A129*), both on Port Shelter.

Distribution of the variety. — Western Australia (type locality), southern Japan, India, Ceylon, Iranian Gulf.

This variety is easily distinguished from the others by the beautiful red of its elegant frond, with larger surface cells (40–60 μ in diameter) projecting at the ends of the branchlets.

9. **Laurencia tenera,** sp. nov.

(Plate I, Figure 6; Plate II, Figures 5–6)

Frons leviter fulvopurpurea, nana, ca. 1 cm. alta, tenera, mollissima, caespitosa, intricata, copiose subflabellatim subcorymbose dichotome vel subdichotome ramosa; segmentis subcylindricis, 0.5–1.5 mm. longis, 0.25–0.55 mm. diam., saepe inter se per haptera peripheralia cohaerentibus; ramulis ultimis subcylindricis vel clavatis, ad apicem late truncatis; in sectione transversali cellulis epidermali-

bus subquadratis, 20–30 μ latis, 20–28 μ altis, haud simili modo ut cellulis valliformibus dispositis; cellulis medullaribus solum ca. 45 μ latis, partem incrassatam lenticulatam ad parietem non ostendentibus; tetrasporangiis sphaericis, 75–90 μ diam., in ramis ramulisque ultimis (qui sunt sterilibus similes) sitis. Cystocarpia et acervuli spermatangiales ignota. Species *Laurenciae nanae* Howe proxima videtur.

Specimen typicum: *Tseng 2600* (in herbario auctoris), ad rupes litoreas, prope Shek-O, Hong Kong I., 16 Dec., 1938.

Frond yellowish to light brownish purple, slender, very soft and somewhat gelatinous to the touch, forming a low caespitose intricate mass about 1 cm. high; abundantly dichotomously or subdichotomously branched in a more or less flabellate and corymbose manner (see Pl. I, Fig. 6). Segments subcylindrical to clavate, 0.5–1.5 mm. long and 0.25–0.55 mm. broad, the diameter varying very slightly in the neighboring segments, often cohering to each other by means of broad peripheral haptera. Ultimate segments broadly truncate at the apices. Epidermal cells in surface view polygonal, 20–30 μ long and broad in the younger segments, becoming more elongated longitudinally, up to 45 μ, in the older ones, with thin and rather indistinct cell walls, not projecting at the ends of the branchlets; in transverse section of the branchlets quadrate to subquadrate, about 20–30 μ broad, 20–28 μ high (see Pl. II, Fig. 6). Medullary cells rather small, mostly of approximately equal size, generally about 45 μ broad, without lenticular thickenings of the walls. Tetrasporangia spherical, 75–90 μ in diameter when mature, scattered near the apices, with older ones below and younger ones above (see Pl. II, Fig. 5). Tetrasporiferous branchlets similar to the ordinary ones. Sexual organs not found.

Habitat. — On surf-beaten littoral rocks, Shek-O, Hong Kong I., in December (*Tseng 2600*, TYPE; *Taam A14*).

The present species is undoubtedly most closely related to *Laurencia nana* Howe from the Bahama Islands, and the writer was at first tempted to refer this plant there as a variety. The two are alike in the dwarf nature of the frond, the frequent occurrence of peripheral haptera uniting the neighboring segments into an intricate mass, and the characteristics of the epidermal cells in transverse section. Having studied some fragments of the type specimen of *L. nana*, however, the writer has come to the conclusion that the Hong Kong plant is distinct enough from the West Indian form to deserve an

independent specific rank. The chief differences between these two species are found in (1) the substance of the frond, which is fragile and easily broken in the Bahama plant and soft and gelatinous in the present species; (2) the branching, which is more fastigiate, with a greater tendency to unilaterality, in *L. nana*, and more open, with more flabellate and equal development on both sides of the branches, in *L. tenera;* (3) the epidermal cells in surface view, those of the former having clearly distinct thick firm cell walls and being predominantly regularly hexagonal and similarly sized throughout the frond and those of the latter being more irregularly polygonal and much more elongated longitudinally in the lower part of the branches and having thin indistinct cell walls; (4) the lenticular thickenings of the medullary cell walls, which occur in the Bahama plant (according to Howe, 1934, p. 41), but are lacking in the Hong Kong one; and (5) the size of the segments, which are narrower but longer in the former species and broader but shorter in the latter.

To a smaller extent the present species also resembles *Laurencia clarionensis* Setch. & Gardn. from Clarion Island of the Revillagigedo Group and *L. Galtsoffii* Howe from Pearl and Hermes Reef. The first of these is, however, a much smaller plant, only 150–225 μ in diameter, and the second is a much more robust one, 460–780 μ in diameter. Both have lenticular thickenings on the medullary cell walls and do not have the peripheral intersegmental tenaculae which characterize *L. nana* and the present species.

10. **Laurencia subsimplex,** sp. nov.

(Plate III, Figures 4–6)

Frons fulvorubra, ca. 3 cm. alta, gelatinose carnosa, caespitosa, e disco lato oriens, simplex vel furcata; filamentis ligulatis, subcylindricis vel compressis vel complanatis, inferne attenuatis, superne dilatatis, apice obtusis, usque ad 4 mm. latis, sine ramulis; cellulis epidermalibus a superficie visis latissime rectangularibus vel multiangulatis, 20–25 μ longis, 30–46 μ latis, in sectione transversali subquadratis vel subrotundis, 36–46 μ altis, 30–46 μ latis, haud simili modo ut cellulis valliformibus dispositis; parietibus cellularum medullosarum incrassationem lenticulatam ostendentibus; partes aliae desunt. Species affinitatis incertae, probabiliter sectionem generis novam formans.

Specimen typicum: *Tseng 2578* (in herbario auctoris), ad rupes

arenosas zonae inferioris litoralis, prope Big Wave Bay, Hong Kong I., 10 Mai., 1938.

Frond brownish red, somewhat gelatinous, very fleshy, about 3 cm. high, caespitose, arising from an extensive basal disc, which sometimes simulates a thickish rhizome. Erect filaments simple or once-furcate, ligulate, subcylindrical in some plants and compressed to strongly flattened in others, attenuated below to stalklike cylindrical parts and expanding above to strap-shaped parts; obtuse at the apices, as much as 4 mm. broad, smooth or slightly wavy at the margin, and entirely without lateral ramuli (see Pl. III, Fig. 4). Epidermal cells in surface view very broadly rectangular or polygonal, seemingly longitudinally compressed, and, superficially, arranged somewhat after the fashion of brick tiers (see Pl. III, Fig. 6), 20–25 μ long and 30–46 μ broad; in transverse section subquadrate or subrotund, 36–46 μ high and 30–46 μ broad, not radially elongated like palisade cells (see Pl. III, Fig. 5). Medullary cells occasionally with lenticular thickenings of the walls. All specimens collected were sterile.

Habitat. — On sand-covered rocks in the lower littoral region, Big Wave Bay, Hong Kong I., in April (*Taam A80*) and May (*Tseng 2578*, TYPE).

The present species is certainly unique among the members of the genus Laurencia. The somewhat gelatinous very fleshy substance of this alga reminds one greatly of members of such genera as Dumontia, in which genus the writer was first tempted to place it, before the study of its internal structure was made. The apical cell sunken in the crater-like pit, the presence of a central siphon and five pericentral cells in transverse section, and the obscure axial cells in the longitudinal section of the filament show clearly its natural place in the genus Laurencia. The simple or furcate ligulate frond without any lateral branchlet is unique, not appearing in any other member of the genus. To be sure, the specimens are young and sterile, but even the very much younger stages of other species of this genus which have a slight resemblance to the present one, *L. undulata*, for instance, show some branching in accordance with the characteristic pattern of the species. Another peculiarity of this species is the arrangement of the epidermal cells, which in surface view are longitudinally compressed, usually about twice broader than long, and arranged somewhat like layers of bricks. Generally the epidermal

cells of members of Laurencia appear hexagonal, subrotund, or polygonal, and subequal in length and breadth or, if unequal, then elongate in the direction of the axis. These peculiar characteristics of *L. subsimplex* isolate it from any of the known species and place it in a unique position. Its much broadened, sometimes compressed or flattened thallus would seem to put it in the section Pinnatifidae. Yet the occurrence of the subcylindrical thallus and the absence of lateral distichous branches make this grouping unjustified. Possibly it is related to the subdichotomous-corymbose species, especially if the tetrasporangia, when found, should be located near the apices, like those of the *Laurencia clarionensis–nana–tenera–Galtsoffii* complex. It also seems to have affinities with *L. humilis* Setch. & Gardn. from Clarion Island, which, like the present species, has a caespitose very sparsely branched frond. The Clarion alga, however, is a diminutive plant (8–15 mm. high, 1–2 mm. in diameter), apparently cylindrical throughout, with epidermal cells subcircular in surface view and medullary cells without lenticular thickenings. Perhaps the Hong Kong alga belongs to a new section of its own. It may even represent an undescribed genus closely related to Laurencia. Fruiting materials, unfortunately not available at present, are needed to settle this problem.

11. **Laurencia parvipapillata,** sp. nov.

(Plate IV)

Frons obscure purpurea, ca. 4 cm. alta, cartilaginea, pulvinata, caespitosa, discis ad saxum adfixa, intricata, ad basim subteres et ca. 0.8 mm. lata, sursum mox complanata ca. 2 mm. lata, pinnate decomposita; ramis ramulisque suboppositis vel alternis, distichis, irregulariter inter se per tenacula adhaerentibus, et ad rupes per rhizoideas secondarias adfixis; ramulis ultimis breviter clavatis, apice truncatis vel leviter rotundatis; cellulis epidermalibus ad partem superiorem mammiformiter projicientibus, in sectione transversali pauce radialiter elongatis, usque ad 30 μ latis, 35 μ altis, cellulis medullaribus partem incrassatam lenticulatam ad parietem non ostendentibus; tetrasporangiis oblongis, usque ad 100 μ latis, 120 μ longis, in ramulis ultimis (qui sunt sterilibus similes) sitis, generaliter ad apicem in una serie dispositis. Cystocarpia et acervuli gametangiales ignota. Species *Laurenciae pinnatae* Yam. proxima videtur.

Specimen typicum: *Tseng 2813* (in herbario auctoris), ad rupes

zonae inferioris litoralis, prope Cape d'Aguilar, Hong Kong I., 6 Jun., 1940. Duplicum in Herb. Univ. Mich.

Frond dull purple, very cartilaginous, about 4 cm. high, pulvinately caespitose, attached by a discoid holdfast. Main axis quite terete near the very base, measuring 0.8 mm. in diameter there, then becoming broadened and compressed above, up to 2 mm. broad; pinnately decompound, with distichous alternate or subopposite branches (see Pl. IV, Fig. 1) which interlock with each other, frequently producing rhizoidal tenacula binding the neighboring segments together (see Pl. IV, Fig. 2) and forming an intricate and almost inextricable mass, which also attaches to the substratum more or less similarly by secondary rhizoids (see Pl. IV, Fig. 3). Ultimate branchlets shortly clavate, truncate, or slightly rotund at the apices. Epidermal cells in surface view generally hexagonal, about 30 μ broad, strongly mammillate and projecting at the ends of the branchlets (see Pl. IV, Figs. 4–5); in transverse section subquadrate or higher than broad, somewhat radially elongated, about 30 μ broad and 35 μ high, with cuticle about 8 μ thick and the conical papillae about 6–8 μ high (see Pl. IV, Fig. 7). Medullary cells without lenticular thickenings of the walls. Tetrasporangia oblong, about 100 μ broad and 120 μ long, very regularly arranged in a ring at the apex of the ultimate branchlet (see Pl. IV, Fig. 6). Sexual organs not found.

Habitat. — Forming an intricate pulvinate caespitose patch on surf-beaten littoral rocks: Cape d'Aguilar, in March (*Tseng 2691*) and June (*Tseng 2813*, TYPE), Repulse Bay, in May (*Tseng 2798*), Aplichau, Aberdeen, in May (*Taam A132*), all on Hong Kong I.; Lamma I., in May (*Taam A119*).

The present species is a member of the Pinnatifidae, closely related to *Laurencia pinnata* Yam., the only other species in the section having surface cells which are mammillate and which project at the ends of the branchlets. The Japanese plant, however, is several times larger than the Hong Kong alga, and entirely different in habit. It is also looser in branching than the present species and does not have the intersegmental rhizoidal tenacula so characteristic of the latter. Moreover, the frond of *L. pinnata* is soft, whereas that of the present species is firm and cartilaginous. Though both species have projecting surface cells, these are not so clear and distinct in the Japanese plant as they are in the Chinese species.

12. *Laurencia undulata* Yam.

Yamada, Notes on Laurencia, 1931, p. 243, fig. T, pl. 29, fig. a.

Frond softly fleshy, reddish brown, complanate, about 7 cm. high, caespitose, arising from a basal discoid holdfast and sparsely pinnately branched. Branches distichous, with rounded axis, attenuated below and expanding upward to about 4 mm. broad. Ultimate branchlets alternate or subopposite, also distichous, and truncate or rotund at the apices, curving slightly upward. Epidermal cells in transverse section irregularly subquadrate, 20–30 μ broad, 26–36 μ long, slightly radially elongated. Medullary cells rather thick-walled, sometimes with annular thickenings. Tetrasporangia oblong, up to 110 μ broad and 160 μ long, situated near the apices of the short stichidious branchlets, which are numerous and crowded on the margin of the minor branches and so form a verrucose ruffled outline. Tetrasporiferous branchlets at times issuing in various directions from the fertile branches, thus producing a very irregular complicated outline and, sometimes, an almost subglobular mass. Sexual organs not found.

Habitat. — In tufts on rocks in the lower littoral region, Hong Kong I.: Stanley Bay, in April (*Tseng 294*), Cape d'Aguilar, in March (*Tseng 2698*), Shek-O, in March (*Taam A72*) and April (*Taam A89*).

Distribution. — Enoshima, Japan (type locality).

The writer compared his material with an authentic specimen identified by Yamada and found that they agree perfectly.

SUMMARY

Fifty-two collections of members of the genus Laurencia from the Hong Kong region have been studied, and were found to belong to twelve species, eight of which are here described for the first time. Of these eight new species, three belong to the section Palisadae, namely, *L. jejuna*, *L. surculigera*, and *L. longicaulis;* two to the section Forsterianae, namely, *L. articulata* and *L. chinensis;* one, *L. tenera,* to the section Cartilagineae; and one, *L. parvipapillata,* to the section Pinnatifidae. The affinities of the remaining new species, *L. subsimplex*, are obscure; it probably belongs by itself in an as yet undescribed section. These eight species are mostly small and inconspicuous, and may eventually be found rather widely in the

South China Sea region, rather than being limited to such a small area as Hong Kong Island and its close vicinity. Of the remaining four species, two were previously known only from the original localities in Japan; these are *L. japonica* and *L. undulata*. Another, *L. paniculata*, is more widely distributed. These three species are recorded here for the first time for the Hong Kong region, and for China, as well. The twelfth species, *L. obtusa*, has been reported from North China under one of its many varieties, var. *intricata;* the particular variety found in the Hong Kong region is var. *majuscula*, originally reported from Australian waters and now added to the floristic list of China as well as that of Hong Kong.

The writer wishes to express his thanks to Professors Wm. Randolph Taylor and H. H. Bartlett, of the University of Michigan, for their advice and help in this study, and to Dr. F. J. Seaver, Curator of Cryptogams of the New York Botanical Garden, who kindly sent specimens of various species of Laurencia needed in this research.

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EXPLANATION OF PLATE I

FIG. 1. *Laurencia jejuna*, sp. nov. Habit sketch of a tetrasporic plant, showing the branching and the tetrasporiferous branchlets. × 4

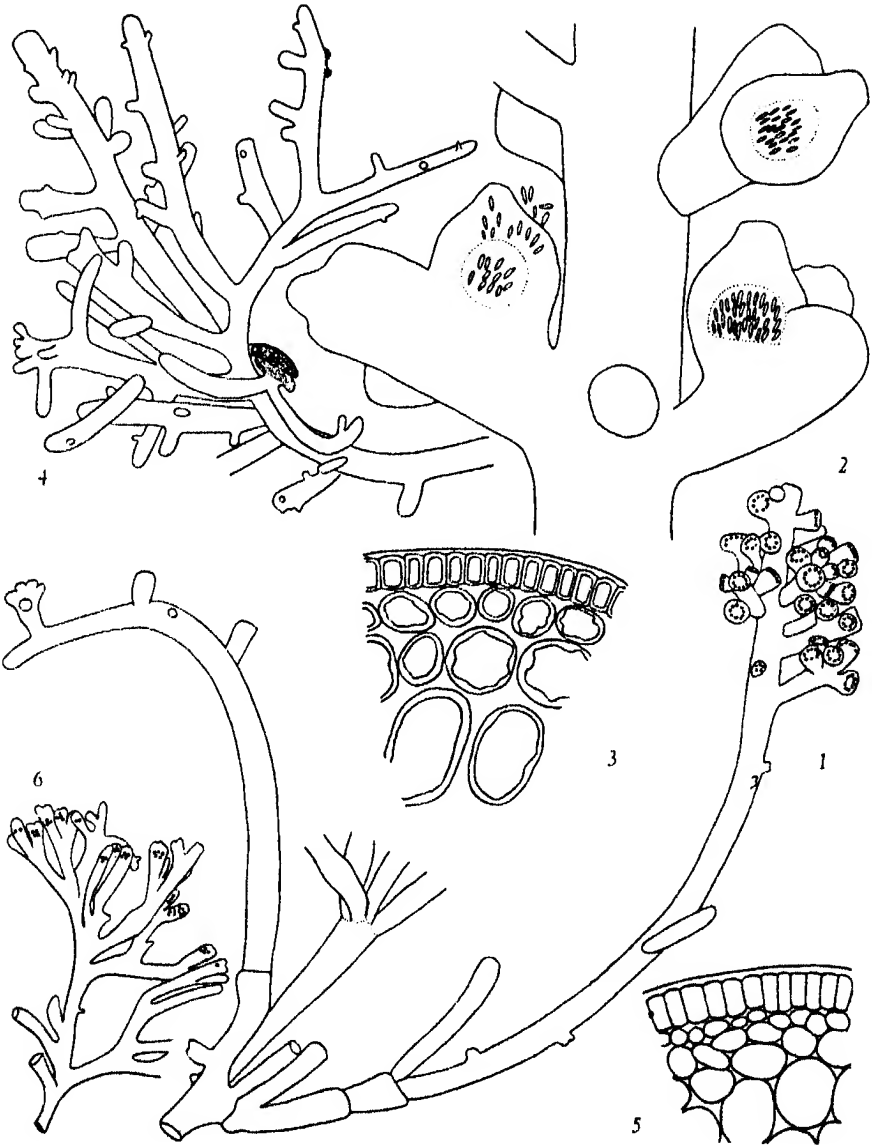
FIG. 2. *L. jejuna*, sp. nov. A part of a fertile branch with cystocarps. × 19

FIG. 3. *L. jejuna*, sp. nov. Transverse section of a branchlet. × 170

FIG. 4. *L. surculigera*, sp. nov. Habit sketch of a young plant, showing the branching and the repent filaments with holdfasts. × 3

FIG. 5. *L. surculigera*, sp. nov. Transverse section of a branchlet. × 110

FIG. 6. *L. tenera*, sp. nov. Habit sketch of a part of a tetrasporic plant, showing the branching and the tetrasporiferous branchlets. × 4



Marine algae of the genus Laurencia

EXPLANATION OF PLATE II

FIG. 1. *Laurencia longicaulis*, sp. nov. Habit sketch of a tetrasporic plant showing the branching and the tetrasporiferous branchlets. × 3.6

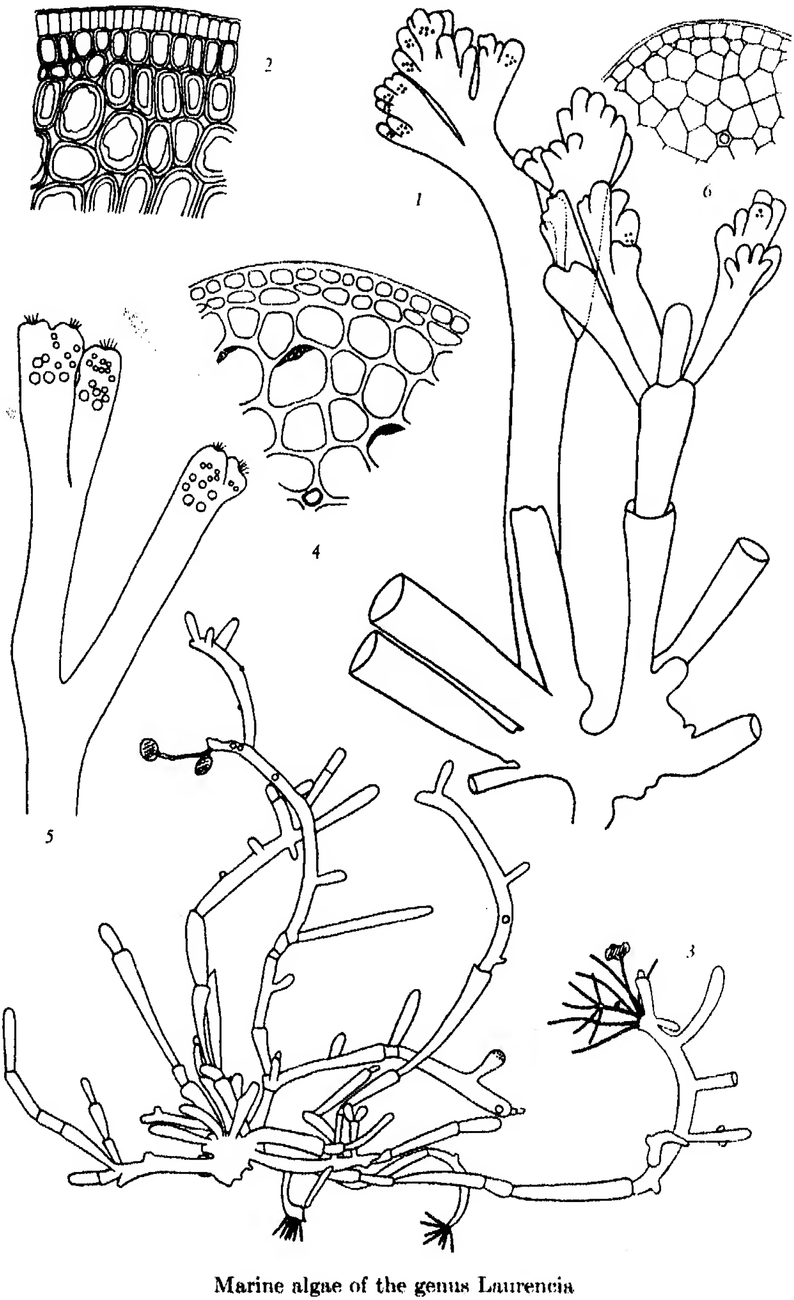
FIG. 2. *L. longicaulis*, sp. nov. Transverse section of a branchlet, showing annular thickenings on the medullary cell walls. × 97

FIG. 3. *L. articulata*, sp. nov. Habit sketch of a young plant, showing the branching, the articulations, the repent rhizoid-bearing branches, and a young tetrasporiferous branchlet. × 2.6

FIG. 4. *L. articulata*, sp. nov. Transverse section of a branchlet. × 97

FIG. 5. *L. tenera*, sp. nov. Upper part of a branch, showing the apices and the position of the tetrasporangia. × 17

FIG. 6. *L. tenera*, sp. nov. A sector of a transverse section of a branchlet. × 97



Marine algae of the genus Laurencia

EXPLANATION OF PLATE III

FIG. 1. *Laurencia chinensis*, sp. nov. Habit sketch of the basal part of a young plant, showing the stoloniferous filament and the branching. × 3

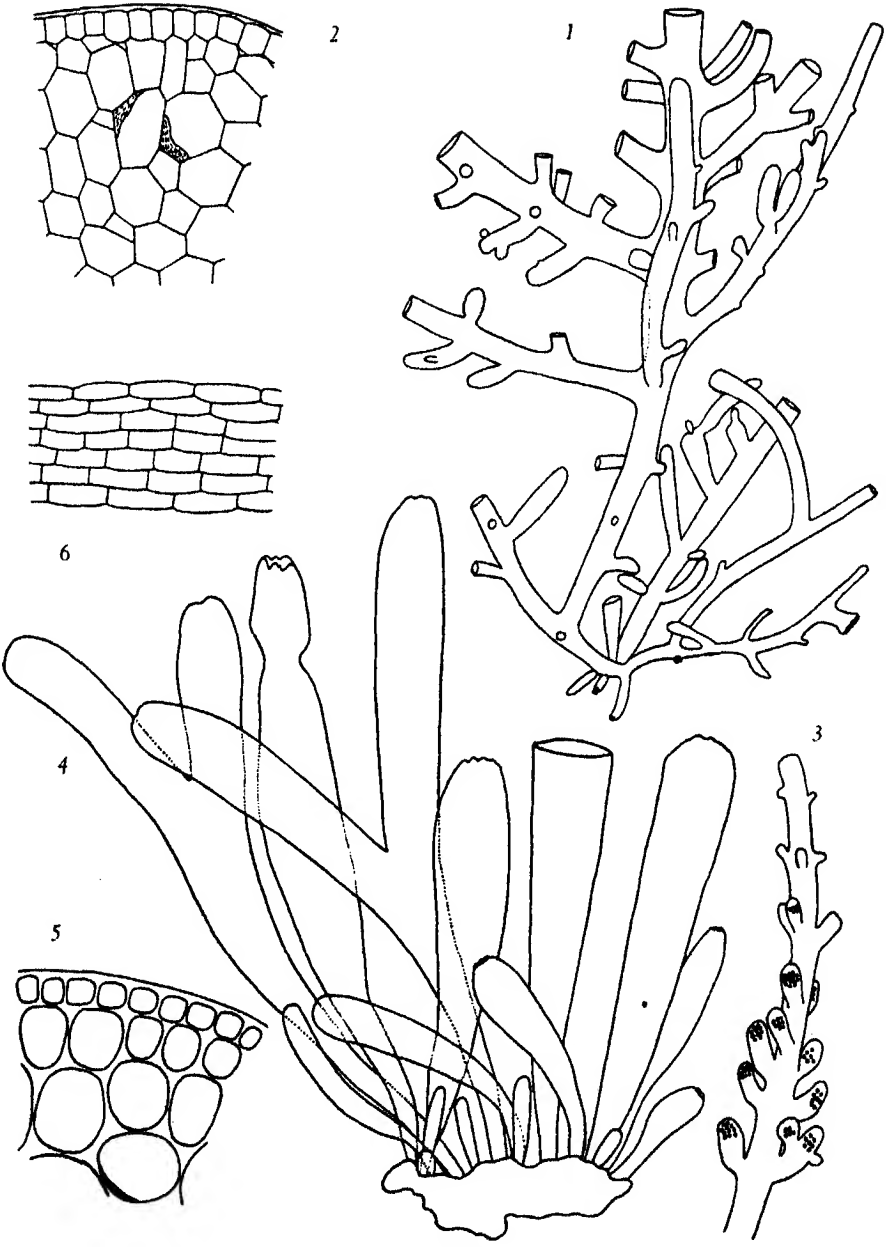
FIG. 2. *L. chinensis*, sp. nov. Transverse section of a branchlet. × 114

FIG. 3. *L. chinensis*, sp. nov. Upper part of a tetrasporiferous branch. × 4.5

FIG. 4. *L. subsimplex*, sp. nov. Habit sketch of a tuft of fronds. × 3

FIG. 5. *L. subsimplex*, sp. nov. Transverse section of a frond, near the tip. × 114

FIG. 6. *L. subsimplex*, sp. nov. Surface view of some epidermal cells near the tip of a frond. × 114



Marine algae of the genus Laurencia

EXPLANATION OF PLATE IV

Laurencia parvipapillata, sp. nov.

FIG. 1. Habit sketch of a part of a tetrasporic plant, showing the branching and two young tetrasporiferous branchlets. × 3

FIG. 2. Parts of two branches, showing cohesion by rhizoidal tenacula. × 4.5

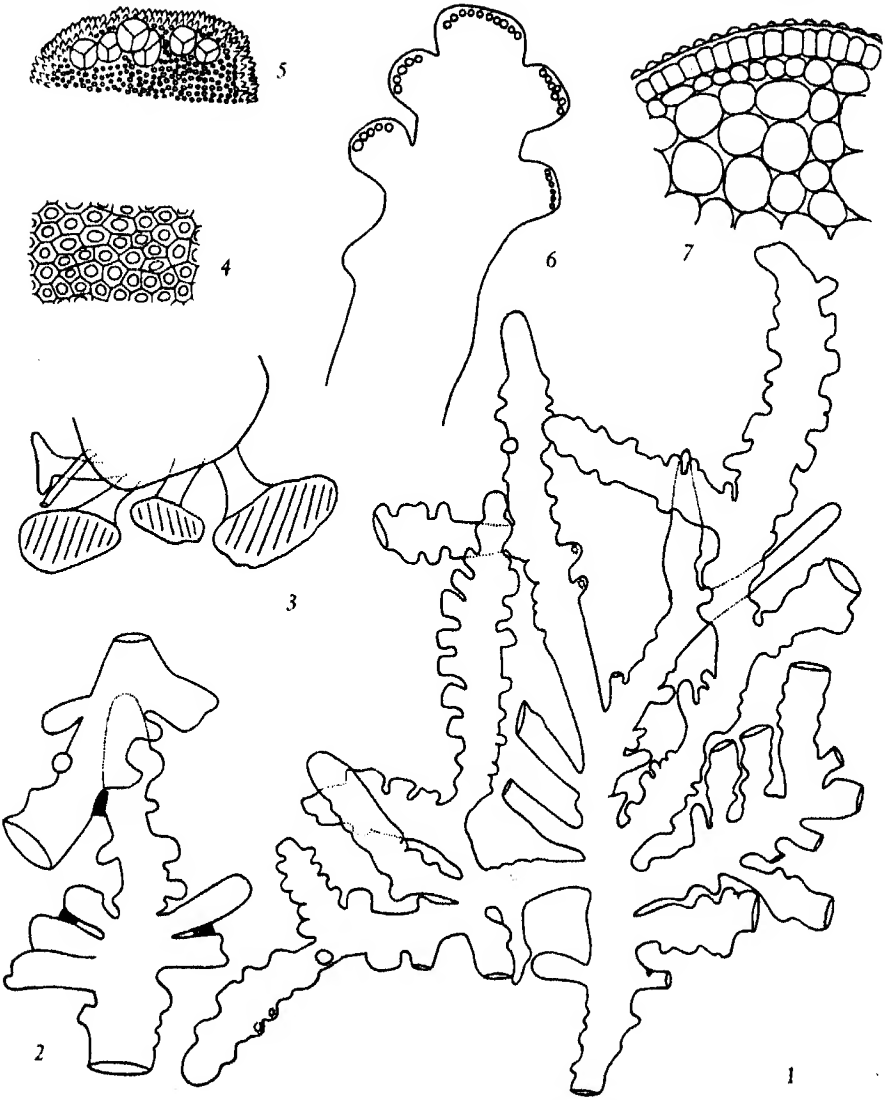
FIG. 3. Basal part of a frond, showing some rhizoids. × 25

FIG. 4. Surface view of some epidermal cells near the tip of a branchlet. × 114

FIG. 5. Surface view of the fertile tip of a branchlet, showing the mammilliform projection of the epidermal cells and some tetrasporangia. × 47

FIG. 6. Upper part of a tetrasporiferous branch, showing the margin of the fertile branchlets with their sporangia. × 12

FIG. 7. Transverse section of a branchlet, showing the papillate epidermal cells. × 114



Marine algae of the genus Laurencia

SEED DEVELOPMENT IN THE MORNING-GLORY (*IPOMOEA RUBRO-CAERULEA* HOOK.)

EDWARD F. WOODCOCK

A STUDY of the literature on the genus Ipomoea gives very little information concerning the morphology of the seed of *I. rubro-caerulea* Hook. Lubbock (2) describes the mature seed, but includes nothing about its early development. The vegetative structure and culture of the sweet potato (*Ipomoea Batatus* Poir.), a related species, has received much attention because of its economic importance (Hayward, 1). A comprehensive survey of the published records on seed production in the sweet potato has been made by Stout (3). The lack of data on the stages of its seed development is explained by the fact that even in regions where the plant grows and flowers abundantly only a few seeds are produced.

Since *I. rubro-caerulea* Hook. is quite similar to *I. Batatus* Poir. in flower structure and also since it produces seed quite abundantly, this study of the complete seed development may be of assistance in explaining the sterility existing in the sweet potato.

DESCRIPTION AND DISCUSSION OF THE MORPHOLOGY OF THE SEED

The stages of seed development were studied by means of microtome sections cut twelve microns thick and stained with Delafield's haematoxylin.

The two-loculed ovary has two anatropous ovules in each locule. The ovules are more or less basal and develop from an axile placenta at the inner angle of each locule. Each ovule (Pl. I, Fig. 1; Pl. II, Fig. 1) is elongated and in cross section is triangular (Pl. I, Fig. 2; Pl. II, Fig. 2). It has a short funiculus, which is curved and much constricted at the point of union with the chalazal region.

The ovule is not differentiated into a distinct integument and nucellus region, as is generally true of ovules. The long micropyle

is formed by an invagination of the ovule near the chalazal region. The epidermis (Pl. II, Fig. 6) consists of flattened cells, each of which has an outer wall that varies in convexity. Sometimes this outer wall is extended to form a short one-celled blunt hair. Underneath the epidermis are two narrower layers of cells, the inner one undergoing marked changes as the mature seed coat is formed. Vascular tissue enters the ovule from the funiculus and passes through the dorsal region of the ovule to the base of the embryo sac. From this point it proceeds through the ventral region between the embryo sac and the surface of the ovule almost to the micropylar region (Pl. II, Fig. 1).

At the time the embryo begins to enlarge it is furnished with a broad many-celled spindle-shaped suspensor (Pl. II, Fig. 9). The embryo sac is lined with cytoplasm and endosperm nuclei. By the time the embryo has produced well-marked cotyledons (Pl. I, Fig. 3) the endosperm is cellular in the micropylar region of the embryo sac, and the sac is crescent-shaped when observed in cross section. The convex side of the sac is toward the dorsal side of the ovule, and the edges of the sac partly enclose a ventral ridge that extends the length of the ovule. This ridge consists of vascular tissue surrounded by parenchyma. As development of the embryo continues the two cotyledons become thin and extend the length of the embryo sac. Each cotyledon is deeply bifid at the apex and cordate at the base. A cross section of the ovule at this stage just above the notch in the cotyledons (Pl. I, Fig. 6; Pl. III, Fig. 10) shows the shape of the embryo sac, and the folding of the cotyledons about the ventral ridge inside the ovule. At the pointed basal end of the ovule this ridge is divided, which causes the embryo sac to be divided into a central lobe and two lateral ones. In a cross section through the ovule just below the base of the cotyledons (Pl. I, Fig. 7; Pl. III, Fig. 11) the basal lobes of the cotyledon are evident in the lateral lobes of the embryo sac. The central lobe of the sac contains the plumule, which is partly surrounded by the stalks of the cotyledons. At this stage of development the region about the embryo in the embryo sac is filled with a cellular endosperm, the cells of which are large and thin-walled and contain only a few starch grains.

As the further development of the seed occurs the area of the cotyledons increases very much, and as a result of their close confinement inside the seed coat they become much folded transversely

and to some extent longitudinally (Pl. I, Figs. 4–5; Pl. II, Figs. 7–8). The radicle and hypocotyl also are pushed into the narrow pointed end of the seed. The plumule appears as a lobed elevation at the base of the cotyledons. The embryo is surrounded by a cellular endosperm, in which only a few starch grains are visible.

There occurs a further folding of the cotyledons of the embryo as the seed matures. In the mature stage (Pl. I, Fig. 8; Pl. III, Fig. 14) the much-folded cotyledons are evident as they are wrapped about the ventral ridge. The cellular endosperm extends into the folds of the cotyledons, and its cells have only a few starch grains. Since some storage tissue is in the form of endosperm, the mature seed may be considered an albuminous type. The large embryo contains an abundance of stored food. The seed coat (Pl. III, Fig. 13) consists largely of the modified second layer of cells under the epidermis. These cells have increased markedly in their radial dimension, appearing as narrow cells perpendicular to the surface of the seed. Their walls are rather thin, but they are suberized, so that the layer of cells serves as a very efficient protection against loss of water from the mature seed. Figure 9 of Plate I and Figure 12 of Plate III show the cross section of the folded cotyledons of a mature embryo. Figure 3 of Plate II illustrates the two cotyledons of a young seedling after the folds had been pressed out of them. Each cotyledon has a deep apical notch and two basal lobes. Figures 4 and 5 of Plate II show the ventral and dorsal views respectively of a complete embryo removed from the seed coat. The folding of the cotyledons is more evident in these sketches than in sectional views.

SUMMARY

The ovule of *Ipomoea rubro-caerulea* Hook. is anatropous, elongated, and triangular when observed in cross section. There is no distinct integument in the ovule. The micropyle is formed by an invagination of the end of the ovule next to the funiculus. As the seed matures the cotyledons of the embryo become much folded and wrap about a ventral ridge of tissue, which extends inward from the seed coat. The mature embryo is surrounded by a cellular endosperm, in which there is a scarcity of starch grains.

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EXPLANATION OF PLATE I

Stages in development of seed of *Ipomoea rubro-caerulea* Hook.

Fig. 1. Longitudinal section of ovule. × 8

Fig. 2. Cross section of ovule, with embryo sac and endosperm nuclei. × 10

Fig. 3. Longitudinal section of ovule, with embryo and suspensor. Cellular endosperm evident in micropylar region of embryo sac. × 8

Fig. 4. Median longitudinal section of young seed. Radicle, hypocotyl, and plumule well developed. Cotyledons folded. Embryo surrounded by cellular endosperm. × 7

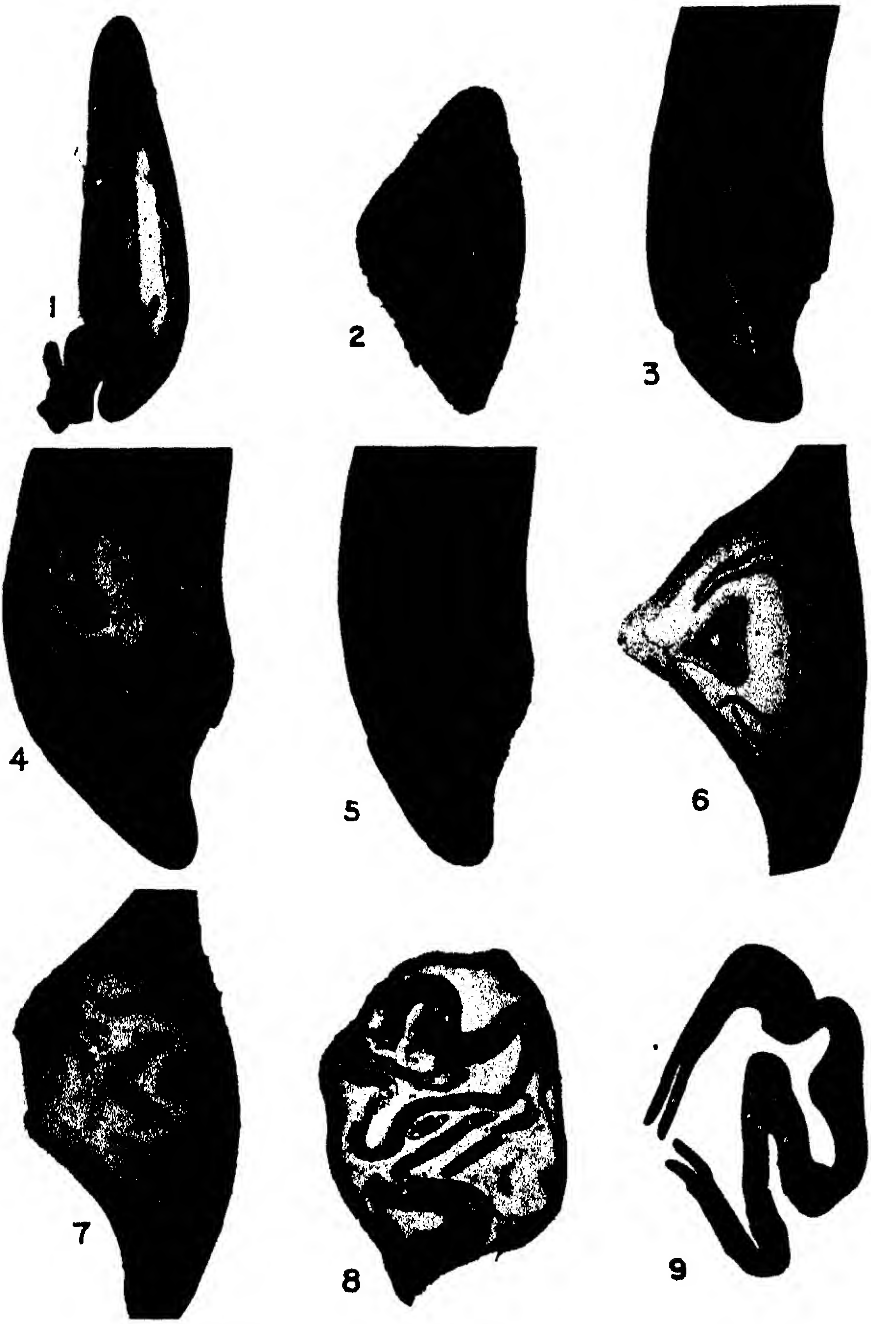
Fig. 5. Longitudinal section cut to one side of median section. Extensive folding of the cotyledons evident. × 7

Fig. 6. Cross section of partly mature seed. Cotyledons folded about ventral ridge, which projects into the embryo sac. × 7

Fig. 7. Cross section of partly mature seed through the micropylar end. Basal lobes of cotyledon, stalks of cotyledons, and plumule are evident. × 9

Fig. 8. Cross section of mature seed. × 9

Fig. 9. Cross section of cotyledons of mature embryo. × 7



Seed development in *Ipomoea rubro-caerulea* Hook.

NOTE

Seed of Ipomoea rubro-caerulea Hook.

All figures drawn with the aid of a camera lucida or a binocular microscope. The following abbreviations are used: C, cotyledons; CL, basal lobe of cotyledon; CS, seed coat; E, embryo; EN, endosperm; EP, epidermis; ES, embryo sac; F, funiculus; H, hypocotyl; M, micropyle; P, plumule; R, radicle; S, suspensor; SC, layer of cells which later become elongated to form the major part of seed coat; SCL, elongated, suberized cells of seed coat; ST, stalks of cotyledons; V, vascular tissue; VR, ventral ridge

EXPLANATION OF PLATE II

FIG. 1. Longitudinal section of young ovule, with endosperm in free nuclear condition. Embryo with large many-celled suspensor. Micropyle formed by invagination of ovule. × 16

FIG. 2. Cross section of young ovule and suspensor. × 16

FIG. 3. Outline of cotyledons. Each has a deep apical notch, two long apical lobes, and two short basal lobes. × 1

FIG. 4. Sketch of ventral side of embryo, which has been removed from seed coat

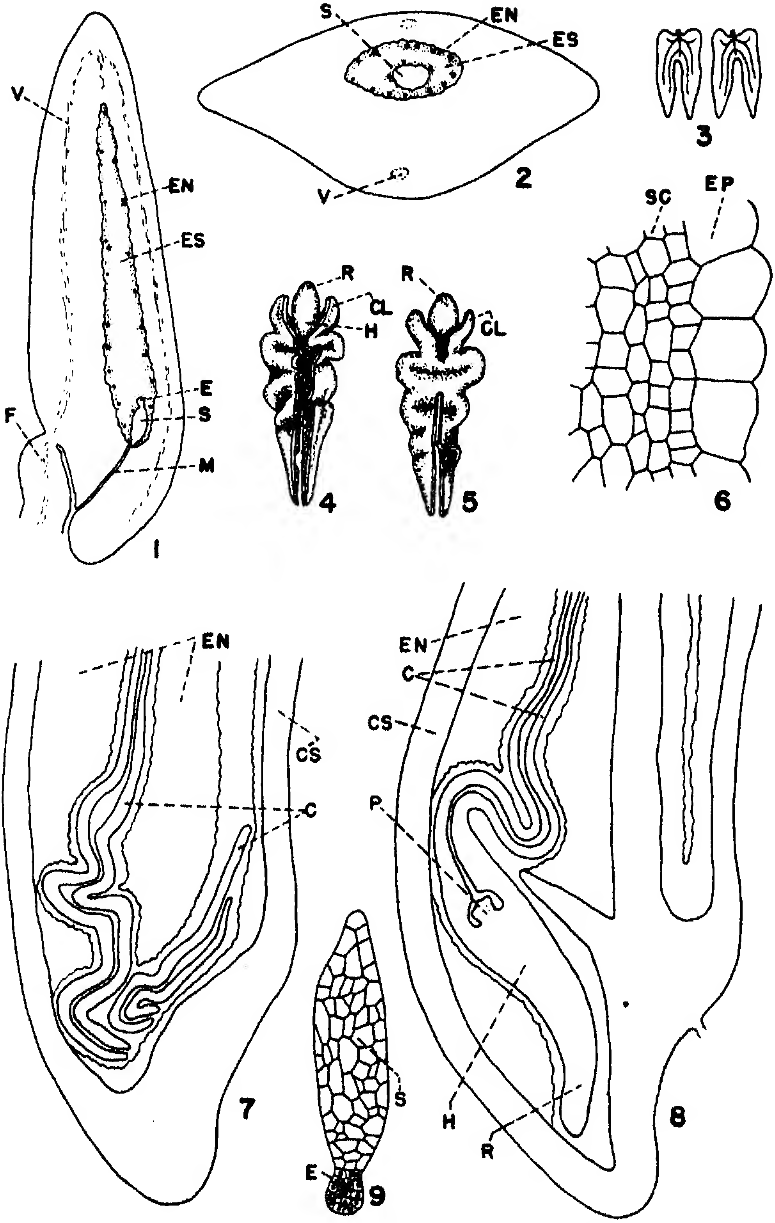
FIG. 5. Sketch of dorsal side of embryo, which has been removed from seed coat

FIG. 6. Cross section of outer region of ovule. Epidermis and underlying layers evident. × 430

FIG. 7. Longitudinal section of partly mature seed, the section passing to one side of the median region. Cotyledons much folded. × 16

FIG. 8. Median longitudinal section of partly mature seed. Embryo surrounded by cellular endosperm. Plumule well developed at base of the folded cotyledons. × 16

FIG. 9. Longitudinal section of embryo and suspensor. × 207



Seed development in *Ipomoea rubro-caerulea* Hook.

EXPLANATION OF PLATE III

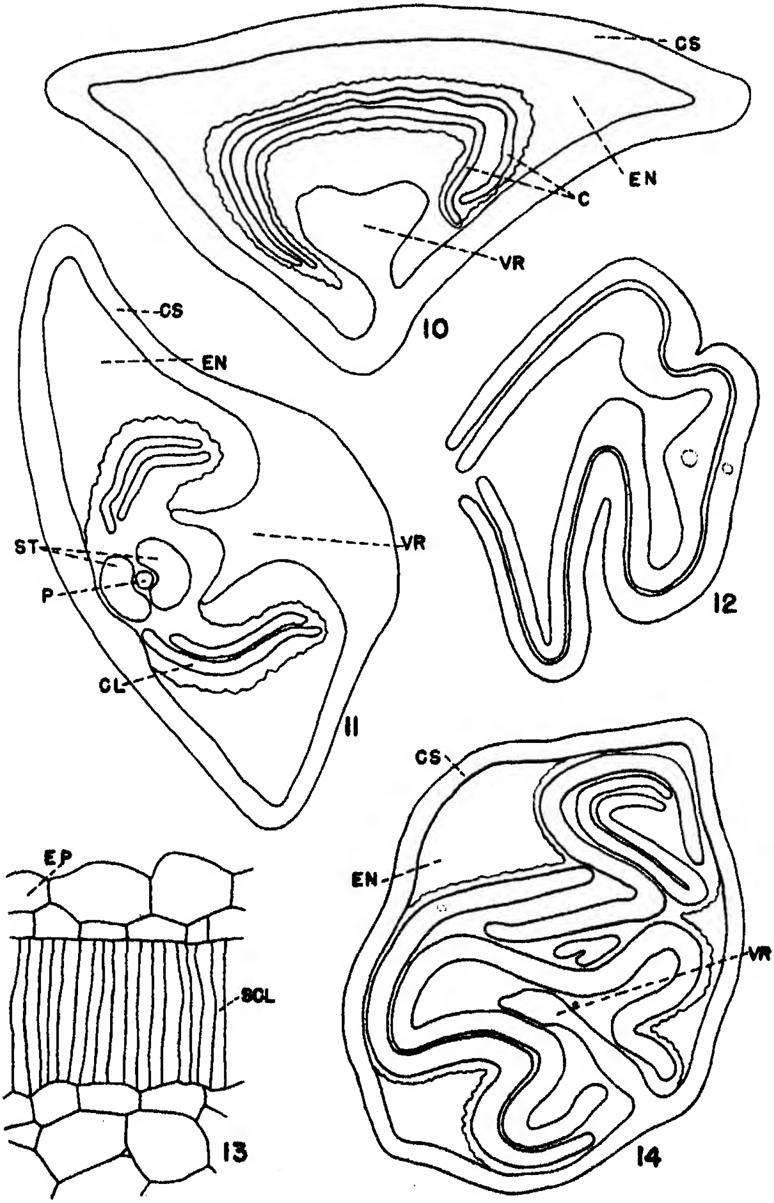
FIG. 10. Cross section of partly mature seed. Thin cotyledons wrapped about the ventral ridge, which extends inward from the seed coat. Cotyledons surrounded by cellular endosperm. × 16

FIG. 11. Cross section of partly mature seed through apical region. Basal lobes of cotyledons evident. × 16

FIG. 12. Cross section of cotyledons of embryo, which has been removed from seed coat. × 16

FIG. 13. Cross section of mature seed coat. Second layer underneath epidermis consists of much-elongated suberized cells. × 430

FIG. 14. Cross section of mature seed. Cellular endosperm next to seed coat in folds of embryo. Ventral ridge evident. × 16



Seed development in *Ipomoea rubro-caerulea* Hook.

FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XIV *

DOW V. BAXTER

A LARGE number of resupinate polypores of northern Europe and Asia are indigenous to the region of the Great Lakes. Furthermore, the majority of porias which occur in Michigan, Minnesota, and Wisconsin can be found throughout the United States. There are, however, certain variants and forms of these fungi in different localities; some are correlated with the occurrence of different types of substrata, and others exhibit macroscopic variations due to moisture conditions.

Races or strains likewise occur, and can be separated from each other largely on the basis of their growth reactions in culture. *Poria laevigata* is one of many examples that might be cited. The race of this species on hickory differs from that on birch in culture (3). See Table I for its characteristics in culture.

It is evident that study of the resupinate polypores involves work in the field, not only within the limits of the state boundaries in the region of the Great Lakes, but in other areas as well. Resupinate plants from two continents have been observed in nature and in the laboratory, and numerous collections from Asia, particularly Siberia, have been compared with ones in Leningrad and western Alaska.

* Throughout the work on these monographs I am indebted to many individuals and institutions for suggestions, help, and privileges extended to me. My appreciation is expressed particularly to the men who have accompanied me on my ten expeditions to Alaska, the Yukon Territory, and the Northwest Territories. Much credit is due them for aiding in the collection and care of specimens and for living, at times, under rather difficult circumstances. I am under obligation to Professors T. G. Halle and Gunnar Samuelson, of Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of association. Thanks are due several American institutions and scholars also. To the authorities at the New York Botanical Garden, to Dr. W. H. Long, Albuquerque, New Mexico, to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture, and to Professor H. H. Bartlett, of the University of Michigan, I am especially indebted.

TABLE I

GROWTH CHARACTERISTICS OF CERTAIN RESUPINATE POLYPORES ON MALT AGAR

Name	In Light						In Dark				
	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Character of margin	Agar discoloration	Pore formation	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Agar discoloration	Pore formation
Poria crustulina on white spruce from Alaska	8.8	White	Cottony to slightly silky	Indefinite	None	None	13.2	White	Cottony, concentric-ring growth	None	None
Fomes robustus on *Betula nigra* from Great Falls, Virginia	...	Olive ochre or yellow ochre to cinnamon buff	Silky to chamois, concentric	Definite	None	None	...	Chamois to antimony yellow to cinnamon brown	Silky to chamois	None	None
Poria laevigata on *Betula nigra* from Great Falls, Virginia	...	Pinkish buff to buckthorn brown	Cottony	Indefinite	Dark red at margins	None	...	Buckthorn brown	Cottony	Very slight	None
Poria corticola on aspen from Mud Lake, Michigan	26.5	White	Granular	Indefinite	None	On inoculum	26.8	White	Granular to chamois	None	Slight on inoculum

Paper XIV discusses twelve species of resupinate polypores and includes the description of one new plant.

Polyporus pallescens Karst., *p. p.* (non Fries), ex Romell, Hymen. Lap., p. 19. 1911

(Plate I)

Polyporus vitreus Pers. *sensu* Karsten. Herb. Bresadola, Stockholm.

Important specimens:

Polyporus pallescens Karst. on Betula, Björkliden. Herb. Mycolog. Lars Romell, Stockholm. Hymen. Lap. 1910.

Polyporus pallescens Karst. on *Pinus silvestris*, Kalixfors. Herb. Mycolog. Lars Romell, Stockholm. Hymen. Lap. 1910.

Polyporus pallescens Karst. on Betula, Torneträsk. Herb. Mycolog. Lars Romell, Stockholm. Hymen. Lap. 1910.

Physisporinus vitreus Pers., *sensu* P. A. Karsten *p. p.*, on Betula, Mustiala. Herb. Bresadola, Stockholm.

Fructification annual, resupinate, effused up to 9 cm., often cracking, as in *Poria subacida*, upon drying, or effused-reflexed, the pileus in such specimens 20 × 10 × 3 mm., drying thin and Stereum-like, pubescent to almost glabrous, "cartridge buff," with "army-brown" margin; margin incurved, paper-thin, less than 0.3 mm. thick, brittle; resupinate plants up to 3 mm., usually about 1.5–2 mm., thick; margin pubescent, wavy or opening in fan-shaped extensions of the fungus, mostly adpressed to the substratum and Stereum-like, 0.5–10 mm. wide, "ivory yellow," "light buff," or "seashell pink," mostly remaining sterile, but occasionally becoming fertile; subiculum thin, less than 0.3 mm. wide, "light buff"; tubes 0.5–2.5 mm., mostly 1 mm., long; mouths white, drying to "ivory yellow," "warm buff," and occasionally to "snuff brown," 4–6 to a mm.; dissepiments thin; spores 2-guttulate, 3–4 × 1.5–2 μ; hyphae soft, not fibular, hymenial hyphae 2–3 μ in diameter, hyphae of the subiculum 3–4 μ in diameter, hyphal pegs present, often encrusted and resembling cystidia.

Allied species. — *Polyporus pallescens* is distinguished from *Pol. euporus* by its lack of cystidia and by the smaller pores. Nor are the tubes and mouths pink or reddish in *Pol. pallescens*. Published discussions of this species and *Poria byssina* point to similarities with reference to color and even to microscopic features. *Pol. pallescens* is more watery when fresh, dries hard, and

frequently curls up at the edges. Its Stereum-like border is distinctive. Dried specimens may suggest *P. undata* (Pers.) Bres., but the conspicuous Stereum-like margin in *Pol. pallescens* again serves to separate the two plants.

Bourdot and Galzin (2) call attention to the resemblance of the plant to *Coriolus Genistae* Bourd. and Galz., but they point out minute differences in the hyphal characters of the two plants. All the hyphae of *C. Genistae* are said to be of similar size. I have not seen this species.

Romell (4) states that *Polyporus pallescens* is the plant that Karsten found at Mustiala, in Finland, on the hymenium of *Fomes fomentarius*. Karsten's other collections belong to *Pol. velutinus*. This plant is not *Pol. pallescens* of Fries, which seems to be identical with *Pol. fumosus, holmiensis, salignus,* and *scanicus*, so far as authentic specimens in the Kew Herbarium are concerned.

The incurved paper-thin pileus-like margins of some specimens may suggest *Polyporus floriformis*. The imbricate pilei of that species will readily serve as a distinguishing feature.

Habitat. — *Betula nigra, Nyssa sylvatica, Picea glauca, Pinus contorta, Prunus cerasus.*

Distribution. — Alberta, Yukon Territory, North Dakota, West Virginia.

Poria mutans Pk., Forty-third Rep. New York State Mus., p. 30. 1890

Type:

***Poria mutans* Pk. on decaying wood of deciduous trees, Selkirk, New York. Coll. C. H. Peck, Aug. New York State Herb., Albany, N. Y.**

Fructification often effused for 30 cm. or more, annual, drying hard and firm; margin abrupt, sterile when young, becoming entirely fertile; subiculum mostly less than 1 mm. thick; tubes up to 6.5 mm. long, mostly about 4 mm., yellow when fresh, drying "ecru drab" to "dark vinaceous brown"; mouths 3–6, mostly 4, to a mm., drying from yellow to "light pinkish cinnamon" or "dark vinaceous drab"; spores ellipsoidal or nearly globose, hyaline, $3\text{–}5 \times 2.5\text{–}4\ \mu$; no cystidia; hyphae often encrusted, seldom branched, $2.5\text{–}4\ \mu$ in diameter; clamp connections present.

Allied species. — *Poria mutans* is allied to *P. spissa* (Schw.) Cooke. Both plants change from yellow or orange to red upon drying. *P. mutans* is harder and frequently cracks up into segments upon drying. Its spores are globose or nearly so and measure 3–5 × 2.5–4 μ, whereas those of *P. spissa* are 4–5 × 1 μ.

Polyporus croceus Pers. ex Fries occurs commonly on chestnut, as does *Poria mutans*. *Pol. croceus*, furthermore, is also buff or orange when fresh and becomes reddish brown upon drying. In addition, the spores of these two fungi are similar. The tubes of *Pol. croceus* are, however, much longer on the average than those of *P. mutans*, ranging from about 5 to 20 mm. *Pol. croceus* is usually pileate.

Habitat. — *Castanea dentata, Juglans cinerea, Quercus sp.*

Distribution. — Ontario, Alabama, California, Connecticut, District of Columbia, Kentucky, Maryland, Michigan, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, Virginia, West Virginia.

Occurrence. — *Poria mutans* is commonly distributed throughout the range of chestnut, often fruiting on the ends of old logs and in hollow butts of this tree. It is one of the few fungi of the genus that occur on charred logs and decay burned slash.

Decay. — *Poria mutans* is associated with a pocket rot. Frequently the decay is so far advanced when fruiting plants are found that the logs attacked consist of only concentric layers of reddish-brown rotten wood loosely held together. The type of decay associated with it is, therefore, similar to that produced by *Polyporus croceus*.

Poria mutans tenuis Pk., Forty-third Rep. New York State Mus., p. 39. 1890

Type:

Poria mutans tenuis **Peck on wood and bark of spruce, Sevey, New York. Coll. C. H. Peck, July. New York State Herb., Albany, N. Y.**

Fructification annual, separable, effused for 12 cm. or more, thin; margin sterile, 1 cm. or more wide, "vinaceous cinnamon"; subiculum less than 0.3 mm. thick; tubes less than 0.5 mm. long; mouths yellowish when fresh (Peck), drying "pinkish cinnamon" or "onion-skin pink" to "burnt umber," 3–4, mostly 3, to a mm.; basidia 12–18 × 3–6 μ; spores cylindric or allantoid, 4–5 (6)

$\times$ 1–2 μ; no cystidia; hyphae of subiculum thin-walled, sometimes branched, often encrusted, 2–4 μ in diameter; clamp connections present.

Allied species. — This plant is characterized by its thinness and by the "onion-skin-pink" color. It differs from *Poria mutans* not only in its color when dried but also in the fact that it is not hard and bony in herbarium specimens. The microscopic features are generally similar, although the spores are more nearly globose in *P. mutans* and cylindrical or allantoid in *P. mutans tenuis*.

It is, however, difficult to distinguish *Poria mutans tenuis* from *P. purpurea*. The combination of characters such as the "onion-skin-pink" color when dry and the generally shorter spores of *P. mutans tenuis* serve to separate the two plants. The spore character alone, like the color feature by itself, however, is not always reliable. Measurements of the spores of the two plants may be similar, but in most specimens the spores of *P. purpurea* are 5–8 (6–7 $\times$ 2) 2–2.5 μ, whereas those of *P. mutans tenuis* are 4–5 (6) $\times$ 1–2 μ.

Habitat. — *Aesculus californica.*

Distribution. — California, New York, Virginia.

Polyporus nidulans Fr., Syst. Myc., 1:362. 1821

Boletus rutilans Pers., Ic. Descr. Fung., p. 18. 1798.
Pol. rutilans Fr., Syst. Myc., 1:363. 1821.
Hapalopilus nidulans Karst., Rev. Myc., 3:18. 1881.
Inonotus nidulans Karst., Fin. Basidv., p. 332. 1889.
Hapalopilus rutilans (Pers.) Murr., Bull. Torr. Bot. Club, 31:416. 1904.

Fructification annual, spongy and watery when fresh, friable when dry, effused, reflexed, 1.5–5 $\times$ 2–8 $\times$ 0.5–2 μ, or occasionally resupinate; surface reddish or cinnamon to yellowish brown, "pecan brown" to "cinnamon buff," velvety or fibrillose to glabrous, azonate; margin purplish or red where bruised; context concolorous with pileus, turning purplish then colorless with KOH, 2–10 mm. thick; tubes concolorous, 1–7 mm. long; mouths grayish to brown, 2–4, mostly 2–3, to a mm.; basidia 4–5 μ in diameter; spores hyaline, smooth, globose, or ovoid, 2.5 $\times$ 3 μ; no setae; hyphae somewhat branched, thick-walled, 4–6 μ in diameter.

Allied species. — *Polyporus nidulans* is separated from *Pol. radiatus*

by the fact that setae, although rare in *Pol. radiatus*, do not occur at all in *Pol. nidulans*.

Habitat. — *Acer saccharum, Alnus sp., Betula lenta, B. occidentalis, Carya sp., Castanea dentata, Populus tremuloides, Quercus coccinea, Vitus sp.*

Distribution. — Ontario, Idaho, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New Mexico, New York, Ohio, Pennsylvania, South Dakota, Tennessee, Virginia, Wisconsin.

Occurrence. — *Polyporus nidulans* is common on hickory and oak.

Polyporus radiatus Sowerby ex Fr., Syst. Myc., 1 : 369. 1821

Boletus radiatus Sow., Eng. Fungi, pl. 196. 1799.
Inonotus radiatus (Sow.) Karst., Rev. Myc., 3 : 19. 1881.

Fructification mostly sessile, imbricate, 2–5 × 2–8 × 0.3–1.5 cm., but semiresupinate at times, yellow brown to rusty brown, "honey yellow" to "antique brown," upper surface velvety to glabrous, usually zonate; context "Sayal brown" or concolorous with pileus, corky, zonate, 2–12 mm. thick; tubes 1–8 mm. long (Overh.); mouths grayish brown, "light buff" to rusty brown, "antique brown," mostly 4–5 to a mm.; basidia 5–6.5 μ in diameter; spores hyaline, smooth, ellipsoid, 4–5 × 3–4 μ; setae rare, projecting 5–10 μ; hyphae rarely branched, 4–8 μ in diameter.

Allied species. — *Polyporus radiatus* is allied to *Pol. cuticularis*, which, however, bears abundant spores and setae. Furthermore, the spores of *Pol. cuticularis* are somewhat longer (5.5–7.5 μ) than those of *Pol. radiatus*. In macroscopic appearance *Pol. radiatus* most closely resembles *Pol. nidulans*, but differs in that setae are not found in *Pol. nidulans*. Birch and alder are common substrata for *Pol. radiatus*, whereas *Pol. nidulans* occurs more widely.

Cultures. — Isolated from *Betula kenaica*, Moose Pass, Alaska. *Polyporus radiatus* belongs to the average-temperature class. The temperature range is small, and the plant grows best in the dark.

One-year-old cultures of the fungus are readily distinguished

from the majority of the members of this group by the yellowish green ("primuline-yellow") mycelium. *Polyporus radiatus* is the only fungus in a lot of 147 species and races that turns the agar olive green in one-month-old cultures.

Wood-block cultures illustrate well the fact that this species seldom occurs on conifers. Red-gum blocks become covered with the mycelium and soon form nodulose growths that resemble abortive fruiting bodies. White-pine blocks in separate cultures or in the same flasks with red gum do not become enveloped by the mycelium.

Habitat. — *Abies Fraseri, Acer rubrum, A. saccharum, Alnus incana, A. sinuata, Betula kenaica, B. lutea, Fagus grandifolia, Juglans nigra, Populus trichocarpa, Quercus Catesbaei, Q. stellata.*

Distribution. — Nova Scotia, Alaska, Connecticut, Florida, Illinois, Massachusetts, Michigan, New Hampshire, New Jersey, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Tennessee.

Occurrence. — This fungus occurs most commonly on birch and alder. Next to *Fomes igniarius nigricans*, it is the most common polypore on these trees in Alaska.

Poria vulgaris Fr. *sensu* Romell, Svensk Botanisk Tidskrift, 20, No. 20. 1926. Not Arkiv für Botanik, 11, No. 25. 1911

(Plates II–IV)

Polyporus biguttulata. Herb. Mycolog. Lars Romell, Stockholm.
Poria calcea (Fr.) Bres. var. *fragilis* Bourdot & Galzin, Hymen. de France. 1927.

Important specimens:

Poria biguttulata. Bromma, 1913. Det. Romell. Herb. Mycolog. Lars Romell 12935, Stockholm.
Polyporus vulgaris, sensu stricto. Saltsjö-Durnäs, 1915. Herb. Mycolog. Lars Romell 12942, Stockholm.

Fructification annual, whitish, somewhat soft, effused in patches extending 10 cm. in length, mostly 1 mm., but up to about 3.5 mm., thick; margin white, 1–2 mm. wide, fimbriate, neither distinctly cottony nor rhizomorphic, becoming fertile; subiculum white, less than 0.5 mm. wide; tubes 1–3.5 mm., mostly 1–1.5 mm., long; mouths white to "cartridge buff," "ivory yellow," sometimes "pale pinkish buff," but those newly formed remaining

concolorous with the white margin and thus producing a distinctly white or light-colored border often 4 mm. or more wide around the plant, somewhat glistening, 4–6, mostly 4–5, to a mm., angular; dissepiments minutely fringed; basidia 7–14 × 4–4.5 (6) μ; spores 2-guttulate, allantoid, not strongly curved, 4–6 × 1–1.5 (2) μ; hyphae occasionally septate, often encrusted.

Allied species. — The interpretation of this species is that of Romell, and is the one held by contemporary workers in Sweden. *Poria vulgaris* is allied to *P. lenis* and *P. xantha.* The chief distinction between it and *P. lenis* is in the spore character. In the latter species the spores are strongly curved so as to form almost a half circle, whereas in *P. vulgaris* they are not strongly curved. During wet seasons or in extremely wet environments *P. vulgaris* may exhibit a soft cottony margin, which may thus appear macroscopically somewhat like that of *P. lenis.* The spore character is a reliable one to distinguish the two plants. Ordinarily, however, the margin described for *P. vulgaris* can be used as a supplementary means of separating them. *P. lenis* is distinctly soft to the touch, usually exhibiting a conspicuously cottony margin and also a fluffy mycelium, which appears in the badly decayed wood in the immediate vicinity of the fruiting structure. It is to be reëmphasized that the typical margin of *P. vulgaris* is fimbriate, more or less adpressed to the substratum, and not generally cottony in nature.

The spores may be used to separate *Poria xantha* from *P. vulgaris,* for in freshly collected *P. vulgaris* they are 2-guttulate, whereas in *P. xantha* they do not exhibit droplets. The sulphurous color of the tubes of *P. xantha* may serve as a supplementary means of distinction between the two species in typical collections.

Poria vulgaris and *Polyporus subfuscoflavidus* may readily be confused, but can be separated by the spore character, supplemented by color features and habit of growth.

In *Poria vulgaris* the spores are narrow, 4–6 × 1–1.5 (2) μ, and usually 1 μ in diameter. Rarely does one find a spore 2 μ in width. Those of *Polyporus subfuscoflavidus* are 4.5–7 × 1.5–2.5 μ. Spores as small as 1.5 μ in diameter are not usual. Bresadola gives a diameter of 2–2.5 μ for his specimens (*P. cinerascens*).

Poria vulgaris is a more fragile plant than *Polyporus subfuscoflavidus,* being by no means so thick and coarse. *Pol. subfuscoflavidus* lacks the thin, almost transparent, margin illustrated in typical specimens of *P. vulgaris.* The ashy color of dried specimens of *Pol. subfuscoflavidus* is helpful in making determinations of herbarium material, but is less useful for diagnosing fresh collections in the field. In mature growing Swedish collections of *P. vulgaris* the mouths are "cartridge buff." In the young stages fresh specimens exhibit a faint blue, something like that of *Pol. caesius,* but this color disappears as the plant ages. In dried collections the tubes and mouths may remain "cartridge buff" or turn darker, to "cream buff," but the marginal areas usually retain their lighter or whitish appearance. This feature is an important one to consider in making determinations.

The name "*vulgaris*" has been confused in herbaria with "*vaporaria,*" partly because a number of different plants are to be found under these names at various institutions. The spores of the two species are similar, but in *Poria vaporaria* the mouths of the tubes are mostly 1–2 to a mm., whereas in *P. vulgaris* they are generally 4–5 to a mm. Moreover, the mouths of *P. vaporaria* do not glisten (see Pl. V).

When *Poria vulgaris* is found growing in extremely wet spots, or when the fruiting bodies have been water-soaked in the field by constant rains, the fungus differs considerably in its macroscopic features from the typical growth forms. In this condition and, except for the pore character, in habit of growth and color, one is reminded of *Corticium lividum.*

Many different growth forms of *Polyporus vulgaris* have received "herbarium" names at European institutions. See Plate II.

Habitat. — *Abies balsamea, A. concolor, Lithocarpus densiflora, Picea Engelmannii, P. glauca, P. Mariana, P. rubra, P. sitchensis, Pinus sp., Pinus Banksiana, P. clausa, P. contorta, P. Strobus, Pseudotsuga taxifolia, Thuja occidentalis.*

Distribution. — Alberta, Northwest Territories, Nova Scotia, Ontario, Quebec, Alaska, California, Florida, Idaho, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oregon, Utah, Wisconsin.

Occurrence. — *Poria vulgaris* is one of the most common members of the resupinate polypores in Sweden, and it occurs much more abundantly in northern Europe than in America. In Sweden it is usual to find this plant on old fence rails, but in this country the poria seldom attacks structural timbers.

Polyporus dichrous Fries, Hym. eur., p. 550. 1821

Gloeoporus conchoides Mont. American herbaria.
Gloeoporus dichrous (Fr.) Bres., Hedw., 53:74. 1914.
Leptoporus dichrous (Fr.) Quél., Fl. Myc. de France, p. 388. 1888.

Fructification annual, sessile, effused-reflexed, 0.5–3 × 1–5 × 0.1–0.5 cm., or sometimes resupinate; surface of pileus white or whitish, velvety to glabrous; margin thin, sterile below; context white, 1–4 mm. thick; tubes flesh-colored or purplish, "fawn color" to "olive brown," less than 1 mm. long, waxy and separable from the context in a thin waxy or gelatinous layer when fresh or moistened; mouths concolorous with the tubes, 5–7 to a mm.; basidia 12–17 × 3–4 μ; spores hyaline, smooth, allantoid, 3.5–4.5 × 0.5–1.5 μ; no cystidia; hyphae thick-walled, somewhat branched, 3.5–4.5 μ in diameter.

Allied species. — There are no plants closely allied to this fungus excepting *Poria taxicola*, which may prove to be the resupinate form of *Polyporus dichrous*. The waxy consistency of the plants, the color of the mouths (flesh to reddish purple), and the spores are similar in the two fungi. Both are found on hardwoods and conifers, but ordinarily *Pol. dichrous* occurs on hardwoods, whereas *P. taxicola* appears on conifers.

Habitat. — *Acer rubrum, A. saccharum, Betula lutea, B. neoalaskana, Cephalanthus sp., Cornus florida, Fagus grandifolia, Fraxinus sp., Hicoria cordiformis, Juniperus virginiana, Larix occidentalis, Liquidambar styraciflua, Liriodendron tulipifera, Melia azedarach, Nyssa biflora, Picea rubra, Pinus caribaea, P. monticola, P. ponderosa, P. Strobus, P. taeda, P. virginiana, Populus balsamifera, P. tremuloides, Pseudotsuga taxifolia, Quercus agrifolia, Q. alba, Q. Garryana, Q. palustris, Q. velutina, Q. virginiana, Rhus vernix, Salix sp., Syringa vulgaris, Taxodium distichum, Thuja occidentalis, T. plicata, Tsuga heterophylla, Ulmus americana.*

Distribution. — British Columbia, Manitoba, Northwest Territories, Ontario, Alaska, Alabama, Arkansas, California, Colorado, Con-

necticut, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Rhode Island, South Dakota, Tennessee, Texas, Virginia, Washington, West Virginia, Wisconsin.

Occurrence. — The fungus usually grows on slash, although occasionally it appears on wood products. It is known, for example, to decay, in storage, turpentine barrels made of slash pine.

Trametes hispida Pass., Nuov. Giorn. Bot. Ital., 4 : 155. 1872

Polyporus Lindheimeri Berk. & Curt., Grevillea, 1 : 50. 1872.
Irpex grossus Kalchbr., in Berk. & Curt., Grevillea, 10 : 57. 1881.
Trametes Peckii Kalchbr., Bot. Gaz., 6 : 274. 1881.
Polystictus scuirinus Kalchbr., in Thüm., Pilz. Fl. Sib., V, 14 : 897. 1882.
Polystictus Fergussoni Cooke, Grevillea, 15 : 23. 1886.
Polystictus Celottianus Sacc. & Manc., in Sacc., Syll. Fungorum, 6 : 249. 1888.
Funalia stuppea (Berk.) Murr., Bull. Torr. Bot. Club, 32 : 356. 1905.

Fructification sessile, effused-reflexed, occasionally subresupinate, imbricate, 2–10 × 2–25 × 0.5–5 cm. (Shope), corky; surface coarsely hirsute or strigose for 1–4 mm., "Sanford's brown" to bay, fading to "cinnamon buff," mostly azonate; margin acute to obtuse, fertile below; context light brown, 0.2–1 cm. thick; tubes concolorous with the context, up to 3 cm. long (Shope), becoming white-stuffed in older parts; mouths angular, averaging approximately 1 to a mm., "buckthorn brown"; basidia 8–10 μ in diameter, projecting up to 12 μ (Shope); spores hyaline, smooth, cylindric, 8–12 (15) × 2–4 μ; hyphae of context either brown, seldom branched, and 5–8 μ in diameter or hyaline, often branched, and 2–4 μ in diameter.

Allied species. — Fortunately *Trametes hispida* seldom grows in an entirely resupinate condition. Frequently, however, only resupinate parts of it are sent in for determination. It is necessary in this group in particular, to have material exhibiting plant margins, if confusion is to be avoided with *T. campestris* Quél. Even the spore measurements of the two species overlap, although most spores of *T. hispida* are shorter, 8–12 (15) μ, whereas those of *T. campestris* are 12–15 μ.

Habitat. — *Acer negundo, A. saccharinum, Hicoria ovata, Juglans sp., Malus pumila, Populus alba, P. deltoides, P. Fremontii, P. hetero-*

phylla, P. tremuloides, P. trichocarpa, Pyrus malus, Quercus velutina, Salix sp., Ulmus sp.

Distribution. — British Columbia, Manitoba, Nova Scotia, Ontario, Yukon Territory, Alaska, Alabama, California, Idaho, Illinois, Indiana, Iowa, Kansas, Maryland, Michigan, Minnesota, Missouri, Montana, Nebraska, New York, North Dakota, Ohio, Oklahoma, Oregon, South Dakota, Tennessee, Vermont, Wisconsin.

Polyporus resinascens Romell, Arkiv für Botanik, 11 : 20. 1911

(Plate VI)

Type:

Polyporus resinascens Romell on *Populus tremula*, Abisko. Herb. Mycolog. Lars Romell, Stockholm.

Fructification resupinate, adnate, 1–2 mm. thick, whitish, becoming mostly "cinnamon," sometimes "warm sepia"; margin 1–2 mm. wide, becoming "cinnamon buff"; tubes becoming resinous in texture, mostly "cinnamon," up to 2.5 mm. long; mouths concolorous with tubes, 2–4, mostly 2, to a mm.; basidia 15–20 $\times$ 4–5 μ; spores 4–5 (7) $\times$ 2–2.5 (3) μ; hyphae fibulate-septate, 2–3 μ in diameter.

Allied species. — *Polyporus resinascens* is allied to *Pol. sinuosa* and may be distinguished from that species by the fact that it dries like resin or horn, which *Pol. sinuosa* does not do. The spores of the two plants are similar.

Romell at first believed this species, which occurs on Salix about Stockholm, to be the true *Polyporus aneirinus* Somm. He states (4), however, that authentic specimens show that *Pol. aneirinus* Somm. is identical with *Pol. serenus* Karst. Both have broader spores, 5–6 $\times$ 3–4 μ, and are consequently distinct from *Pol. resinascens* and *Pol. aneirinus* Fr., which is identical with *Pol. corticola* Fr.

Habitat. — *Populus balsamifera, P. tremuloides.*

Distribution. — Alaska, Wyoming.

Remarks. — This plant, which occurs in Lapland as well as in central Sweden, appears from the records to be distinctly cordilleran, or at least western, in North America. It is probable that this species is much more common in North America than these

records suggest. *Polyporus resinascens* has undoubtedly been given other names in this country.

Polyporus albolutescens Romell, ex Weir, Hymen. Lap., 2:11. 1911

Trechispora onusta Karst., *p. p.*, Hedw., p. 147. 1890.
Poria onusta (Karst.) Bres., *p. p.*, "F. gall.," in Ann. Myc., 1903: 41.

Important specimens:

Trechispora onusta Karst. on Salix, Mustiala. Herb. Bresadola, Stockholm.
Poria onusta (Karst.) Sacc. on birch, Vosges. Legit Galzin. Herb. Bresadola, Stockholm.
Poria albo-lutescens Romell on *Abies grandis*, Coolin, Idaho. Coll. and det. J. R. Weir, Aug. 14, 1920. Pathological and Mycological Collections, Washington, D. C.

Fructification annual, soft, effused occasionally for 24 inches or more, rhizomorphic, the strands frequently penetrating throughout the decayed wood substance, separable, 1–2 mm. thick; margin subiculose, "cartridge buff," "cream buff" to "chamois," tomentose; subiculum conspicuous, about 0.3 mm. thick, concolorous with margin; tubes mostly 2–3 mm. long; mouths "straw yellow" to "mustard yellow" to "primuline yellow" in herbarium specimens, circular to angular, fringed, 2–3, mostly 3, to a mm.; basidia hyaline, clavate, four-spored, $13–20 \times 3–6\ \mu$; spores hyaline, globose to ellipsoidal, angular, $3–5 \times 2.5–4\ \mu$, on sterigmata $3–7\ \mu$ long; hyphae with or without cross walls, clamp connections abundant, $2–4\ \mu$ in diameter; cystidia lacking or rare, $13–18 \times 5.5–9\ \mu$.

Allied species. — *Trechispora onusta* Karst. seems to contain two species, according to Romell — *Polyporus hymenocystis* B. & Br. and the species described by Romell as *Pol. albolutescens*. He states, "As Karsten refers his plant to a separate genus with echinulate spores, which occur in *P. hymenocystis* only, I think it inadvisable to apply his name *onustus* to the present species."

Because of the soft subiculum, *Polyporus albolutescens* suggests most strikingly *Poria subiculosa* Pk. *Pol. albolutescens*, however, retains a yellow color even in herbarium specimens, whereas dried plants of *P. subiculosa* are wood brown. Clamp connections are common in *Pol. albolutescens*, but none are found in *P. subiculosa*.

Habitat. — *Abies grandis, Liriodendron tulipifera, Picea rubra, Pi-*

nus resinosa, Populus trichocarpa, Thuja occidentalis, Tsuga canadensis.

Distribution. — Alaska, Idaho, Louisiana, Michigan, Minnesota, New York, North Carolina, Vermont, Wisconsin.

Poria subincarnata (Pk.) Murr., Mycologia, 13 : 86. 1921

Poria attenuata var. *subincarnata* Pk., Forty-eighth Rep. N. Y. State Mus., p. 118. 1896.

Fructification appearing in patches seldom more than 1 inch in diameter, not separable but often curling up at margins, free from or attached to flakes of bark in dried specimens; margin white, pubescent, 0.5–1 mm. broad; subiculum much less than 0.3 mm. thick, whitish; tubes less than 0.5 mm. long; mouths "tilleul buff" to "pale pinkish buff," angular; dissepiments thin, averaging 5–6 to a mm., entire or coalescing in oblique positions; pore surface cracking when dry; basidia 9–14 × 4 μ; spores hyaline, allantoid, 4–5.5 × 1 μ; hyphae thin-walled, seldom septate, sometimes encrusted, 2–3 μ in diameter, hyphal pegs projecting; no cystidia; no clamp connections.

Allied species. — *Poria subincarnata* is related to *P. sitchensis* Baxter. The spores of the two plants are similar. The resinous margins of *P. sitchensis* and the relatively thick growth habit of that species readily serve to separate the species. Dried plants of *P. sitchensis* do not break up into segments, as is characteristic of *P. subincarnata.*

Habitat. — *Abies balsamifera, Chamaecyparis thyoides, Larix occidentalis, Picea Mariana, Pinus contorta, P. monticola, Tsuga canadensis.*

Distribution.—British Columbia, Newfoundland, Nova Scotia, Idaho, Maine, Michigan, Minnesota, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, South Dakota.

Trametes odorata (Wulf.) Fr., Epicr. Myc., p. 489. 1838

Boletus odoratus Wulf., in Jacq., Collect. ad Bot., 2 : 150. 1788.
Polyporus odoratus (Wulf.) Fr., Syst. Myc., 1 : 373. 1821.
Lenzites saepiaria porosa Pk., in Port. and Coult., Fl. Colo., U. S. Dept. Int. Geol. and Geog. Survey, Misc. Publ., 4 : 164. 1874.
Ochroporus odoratus (Wulf.) Schroet., Krypt. Fl. Schles., p. 488. 1889.
Gloeophyllum hirsutum (Schaeff.) Murr., *p. p.*, Journ. Myc., 9 : 94. 1903.
Trametes protracta Fr. American literature.
Trametes americana Overh., Polyporaceae Penn., Penn. State College, Tech. Bull. 316 : 15. 1935.

Important specimen:

Trametes odorata (Wulf.) Fr. on *Tsuga canadensis*, Bangor, Wisconsin. Coll. Newmann; det. Bresadola. Herb. Bresadola, Stockholm.

Fructification annual or perennial, sessile, coriaceous, rigid, 1–5 × 2–12 × 0.5–2 cm. (Shope); surface "antique brown" to "russet" to blackish, or sometimes weathering and bleaching to "light drab" to "smoke gray," zonate, at first strigose, becoming glabrous or nearly so; margin rounded, hirsute or velvety, tomentose, concolorous or lighter in resupinate specimens, narrowly sterile, or becoming fertile; context yellow or reddish brown, 0.5–3 cm. thick (Shope); tubes 0.3–7 mm. long; mouths poroid or daedaloid, irregular, averaging 1–2, mostly 2, to a mm.; basidia 4-spored, 6–8 × 25–35 μ; spores hyaline, smooth, cylindric to elongate-ellipsoid, 8–12 × 3–4 μ; no setae; hyphae smooth, unbranched, occasionally septate, brown, 2–4 μ in diameter.

Allied species. — *Trametes odorata* has been known under so many names that the problem of deciding which one to use becomes more difficult than determining the plant itself. *T. protracta* is one common name for it. The fungus has also been regarded as a poroid form of *Lenzites saepiaria.* Actually, *T. odorata* may be labyrinthiform, but it is never truly lamellate (see Shope [5]).

Weathered abortive resupinate specimens of *Trametes odorata* suggest *T. carbonaria.* *T. carbonaria* is a much thinner plant, however, and may be recognized further by its habit of interrupted growth. Its spores are slightly smaller also, but the difference is not great enough to be significant.

Cultures. — Differences between *Trametes odorata* and *Lenzites saepiaria* are clearly shown by cultures, as was emphasized by Snell (6). Both fungi have a comparatively high optimum temperature — between 30° C. and 34° C. The upper limits of growth for the two are, however, different. *L. saepiaria* is not inhibited in its growth until after 40° C. is reached, whereas *T. odorata* exhibits only slight growth at 38° C., and does not grow at all at 40° C. *L. saepiaria* develops faster at all temperatures, especially those between 28° C. and 36° C. Snell (6) remarks: "A test of growth upon a single agar at temperatures from 30° C. to 36° C. would serve to distinguish the fungi in culture."

Habitat. — *Abies grandis, Juniperus virginiana, Larix laricina, L. occidentalis, Picea Engelmannii, P. glauca, P. Mariana, P. rubra,*

Pinus Banksiana, P. contorta, P. echinata, P. Lambertiana, P. montana, P. monticola, P. palustris, P. ponderosa, P. resinosa, P. taeda, P. virginiana, Pseudotsuga taxifolia, Quercus sp., Sequoia sempervirens, Taxodium distichum, Tsuga canadensis, T. heterophylla.

Distribution. — British Columbia, Manitoba, Newfoundland, Northwest Territories, Ontario, Quebec, Yukon Territory, Alaska, Alabama, California, Colorado, Florida, Idaho, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, Ohio, Oregon, Tennessee, Utah, Virginia, Washington, Wisconsin, Wyoming.

Occurrence. — *Trametes odorata* most commonly attacks species of the genus Pinus. Although records exist of its appearing on Abies, its ally, *Lenzites saepiaria*, is much more abundant on this genus. Many field records, however, erroneously attribute rot caused by *T. odorata* to *L. saepiaria*, so that the fungus is actually more abundant than it might seem from published accounts.

Remarks. — Fungi usually found on conifers occasionally occur on hardwoods. For instance, there is an authentic record of *Trametes odorata* on an oak railroad tie. It is a well-known fact that many of the wood-destroying fungi found on hardwoods can be cultured on coniferous wood, and that coniferous fungi can likewise be grown on hardwoods in the laboratory. It is to be expected that such conditions may be duplicated in nature. This circumstance points to the relationship between *T. odorata* and *Lenzites trabea* and tends to explain some of the confusion that exists in the synonymy. According to Shope (5): "*T. protracta*, due to misinterpretations by earlier workers . . . appears to be very close to *Lenzites trabea* and probably is conspecific with it."

Poria ossea, sp. nov.

Type:

***Poria ossea*. Bayard, Florida. Coll. C. G. Lloyd. The C. G. Lloyd Mycological Collection 17453. Washington, D. C.**

Fructificatio annua, irregulariter effusa, plus minusve 10 cm. in ligno, siccitate dura firmaque, inseparabilis, 12 mm. crassa; margine abrupto, primum sterili cito omnino fertili, pallide

ochraceo vel griseolilacino vel brunneovinaceo; subiculo distincto, plerumque minus quam 0.3 mm. crasso, albescentiochraceo vel pallide ochraceo; tubis minus quam 4 mm. longis, plerumque 3 mm. longis, non stratis, pallide ochraceis vel fuscoochraceis; aperturis $\frac{1}{5}$–$\frac{1}{3}$ mm. plerumque $\frac{1}{5}$–$\frac{1}{4}$ mm. dimetientibus, primum cum tubis concoloribus sed actione kali caustici obscure purpureis vel fuscopurpureis; basidiis 2-sporis, 11–20 × 4–5.5 μ; sporis hyalinis, 3–4 (5.5) × 2 μ; hyphis hyalinis, saepe ramosis septatisque, fibulatis, membrana tenui septatis.

Specimen typicum conservatum est in collectione Lloydiana, Washington, D. C.; legit C. G. Lloyd, n. 17453, in loco dicto "Bayard," Florida.

Fructification annual, effused for 10 cm. or more in irregular patches on bark or old wood, inseparable, up to 12 mm. thick, drying hard and firm; margin abrupt, sterile at first, becoming entirely fertile, "chamois" to "benzo brown" to "dark vinaceous drab"; subiculum distinct, mostly less than 0.3 mm. thick, "cream buff" to "chamois"; tubes up to 4 mm., mostly about 3 mm., long, not stratified, "chamois" to "Isabella color"; mouths 3–5, mostly 4–5, to a mm., concolorous with the tubes and turning "dull Indian purple" to "dark purple drab" with KOH; basidia two-spored, 11–20 × 4–5.5 μ; spores hyaline, 3–4 (5.5) × 2 μ; hyphae hyaline, frequently branched, thin-walled, often septate, clamp connections present.

Allied species. — *Poria ossea* is allied to *P. mutans* Peck, and *P. spissa* (Schw.) Cooke. The yellow color of *P. ossea* when dried will serve to distinguish it from the other species, which characteristically turn red upon drying. The spores of *P. spissa* are narrow, 3.5–4.5 × 1–1.5 μ, whereas those of *Poria mutans* are ellipsoidal or almost globose or ovoid, 3.5–5 × 2.5 μ. Both *P. mutans* and *P. ossea* become harder upon drying than does *P. spissa*.

UNIVERSITY OF MICHIGAN

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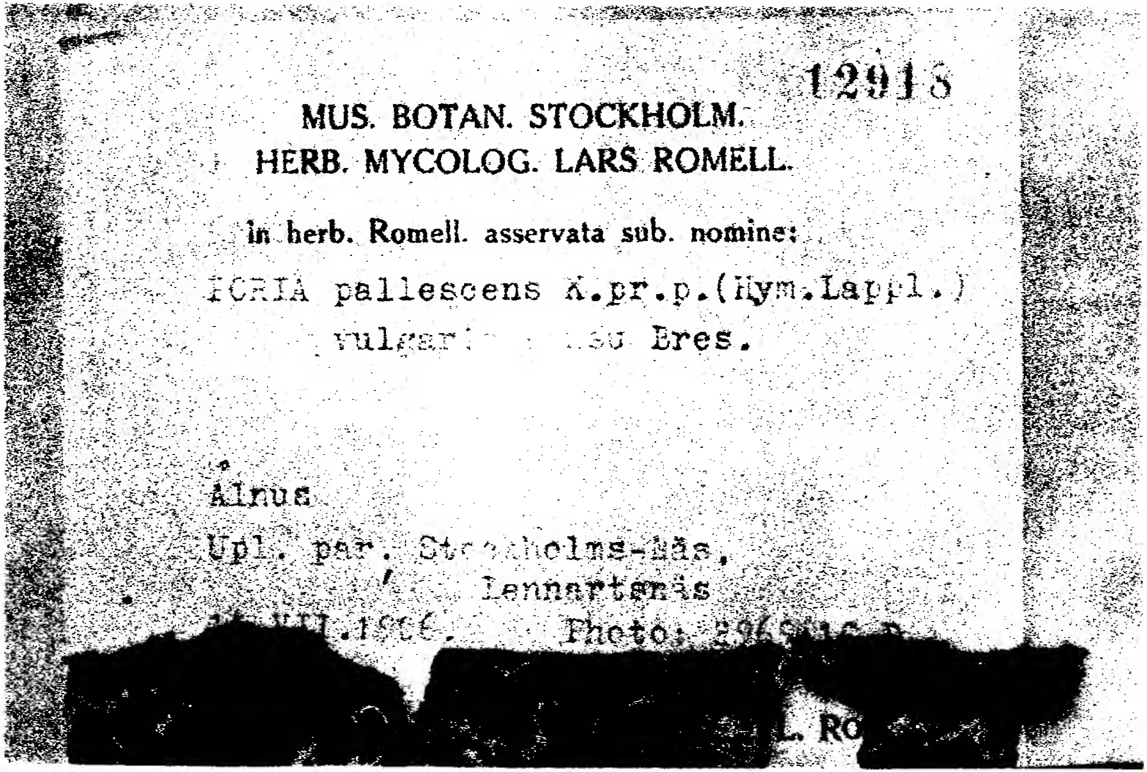
PLATES I–VI



Polyporus (*Poria*) *pallescens* Karst., *p. p.* Herb. Mycolog. Lars Romell, Stockholm, Sweden

FIG. 1. *Polyporus vulgaris subradiosa* on frondose wood, near Stockholm

FIG. 2. *Poria vulgaris subradiosa* on coniferous wood. Det. Romell. Also named *Poria biguttulata* Rom.

FIG. 3. *Poria vulgaris coniferarum*

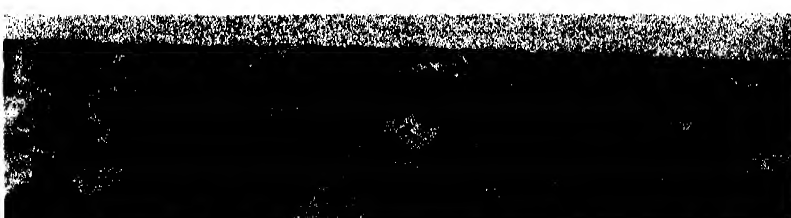
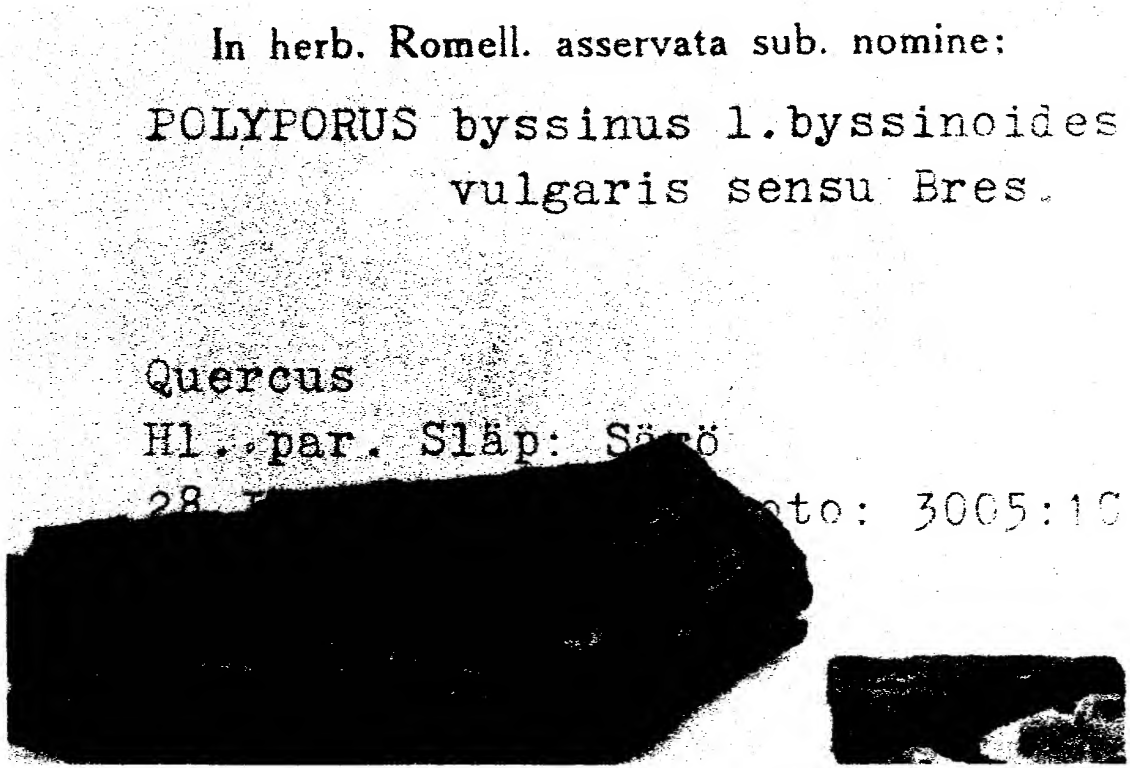


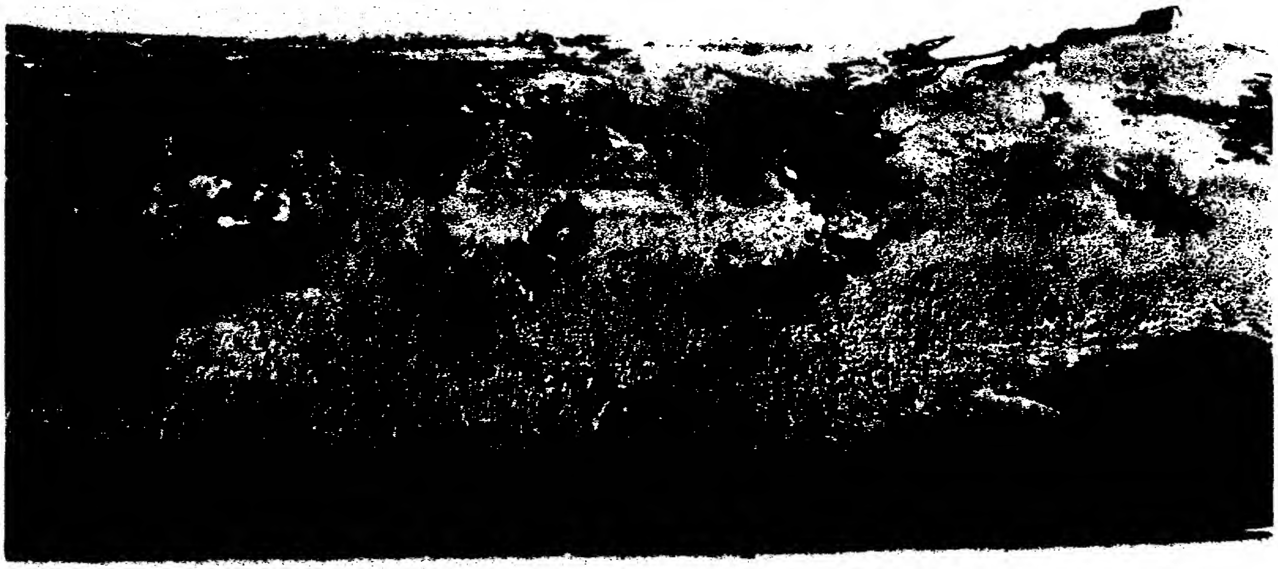
FIG. 4. *Polyporus vulgaris* f. *radiosa* on coniferous wood, near Stockholm

(All four specimens in Herb. Mycolog. Lars Romell, Stockholm)

Polyporus byssinus Pers. on *Corylus avellana*. Sweden. This is Bresadola's interpretation of *Poria vulgaris* according to Romell. Herb. Mycolog. Lars Romell. Stockholm



Polyporus byssinus on *Quercus sp.* Herb. Mycolog. Lars Romell, Stockholm



Poria vaporaria on *Picea excelsa*, near Upsala, Sweden. Coll. Dow V. Baxter, det. Seth Lundell

Polyporus resinascens on *Populus tremula*, near Stockholm. Det. Romell. Herb. Mycolog. Lars Romell, Stockholm

THE INTEGRATION OF NATIONAL-FOREST AND COUNTY PLANNING

RALPH E. CROWELL

LAND-USE planning in one form or another is as old as history and the human race. It will continue as long as people are dependent on land. In Biblical times the shepherd drove his flocks from one grazing ground to another; the American Indian tribes had their hunting grounds and fishing waters and fought among themselves to retain them.

The United States Forest Service has been a manager of public lands since the passage of the Organic Act of June 4, 1897. This act recognized various uses of land, and provided for the interests of settlers, miners, and farmers located within the boundaries of the forest reserves, later called national forests.

The Forest Homestead Act of June 11, 1906, permitted homesteading of lands within national forests chiefly valuable for agriculture. The so-called Classification Act of August 10, 1912, directed the secretary of agriculture to select, classify, and segregate as soon as practicable all lands within the boundaries of national forests that were to be thrown open to settlement under the Homestead Law. This required that specific lands be classified as suitable for either farm crops or forest crops and was one phase of land-use planning.

Unified county planning by committees of local residents under the direction of the Extension Service of the Department of Agriculture represents the most recent and comprehensive step in the evolution of planning that was stimulated by conditions of the depression period. The reader is familiar with the mechanics and purposes of the unified or intensive county-planning procedures, and hence they will not be repeated here. The general consensus, shared by the author, is that this latest attempt to plan use of land by local people in coöperation with interested technical agencies and bureaus is a sound approach and is fundamental to any action program. After observing the process and assisting in the prepara-

tion of the county land-use plan during 1941 in two counties within the Huron National Forest the writer has only one regret — that the plan was not completed many years sooner. The collecting of facts concerning soils, population, natural resources, incomes, tax delinquency, and local governmental service costs for roads, schools, and other functions for the consideration of all interested groups and individuals, with their many diverse viewpoints, is the American way of government. It is an application of the democratic process under the guidance of the technician, who is available to advise on the technical phase of the program but does not dictate the policy of the plans.

It is true that the plan is not perfect, and the men who worked with it would be the first to recognize and admit its shortcomings. At times the members are unduly swayed by the arbitrary ideas of one of their number. Occasionally hope of personal gain influences the classification of certain lands. The county committee may be reluctant to adopt a uniform policy and iron out apparent discrepancies in the local classifications. It is probable that not all interests are represented in the proper proportion, and that agricultural viewpoints dominate.

Land-use planning was conducted in Oscoda and Alcona counties, parts of which are within the boundaries of the Huron National Forest. For the sake of brevity the remainder of the paper will be restricted to comments on the plan for Alcona County, which is a fair sample of northern Michigan counties.

Alcona County's population is 5,000; its gross area is approximately 313,000 acres, of which 269,000, or 86 per cent, are within the Huron National Forest. Of the 107,000 acres in public ownership 85,000 are federal- and 22,000 state-owned.

The land-planning committee classified 2,240 of the 85,000 acres of federally owned lands as primarily valuable for farm purposes, including grazing. Our responsibility as wild-land managers is to do what we can to translate the plan into action. Some of the farmers living adjacent to these lands need more pasture or additional areas for cultivation.

Existing legislation permits the exchange of national-forest lands that are suitable for farming for forest lands of equal value if such an exchange is advantageous to the government. The recommendations of the planning committee have resulted in the initiation of

transfers under the exchange procedures. In this way federally owned farm lands will be returned to private ownership where farmers now own or can purchase forest land to use as a basis for exchange.

The report for Alcona County brings out the fact that many pastures both privately owned and leased from the government are poor and need improvement to increase their carrying capacity. We are now working on an arrangement whereby the pastures leased from the government may be improved by a permittee with his own resources or by loans made by the Farm Security Administration and fertilizer obtained under the Agricultural Adjustment Administration program. All pasture-development plans are to be approved by the county agricultural agent if the pasture improvement is to be on government lands.

The land will continue to be leased to the farmer by the Forest Service until such time as he is in a position to acquire it through exchange, and such exchange will be at wild-land values, and not improved-land values.

It is expected that a considerable part of the federal lands classified for agriculture will not be in demand for development in the immediate future. As a rule, these lands are the more productive forest lands and support thrifty sapling or pole hardwood stands. It is planned to have them continue producing a forest crop until the need for agricultural use arises.

The land-planning committee also lists 5,520 acres in farms that are not suitable for arable farming, and 2,880 acres now in farms that are of doubtful value for farming. The Forest Service can help to place this acreage in proper use in its land-purchase or land-exchange program. The assistance of other agencies, such as the Farm Security Administration, will probably be necessary to work out the relocation of farmers from the poor to the good agricultural lands. Our attempts to date have not been very successful because of the limited amount of money the Forest Service can offer for this type of land and improvements. In addition, the owner usually needs financing when he moves to a new farm. The Alcona report shows that, in general, farmers do not have sufficient cleared acreage to make an economic entity. The Extension Service and the Farm Security Administration are assisting them to develop the proper economic unit.

The Alcona farmer depends to a considerable extent upon the

national forest for building materials, fuel, and other forest products. From sixty to seventy "sales at cost" ($1.00/MBM) are made annually to Alcona County farmers for fence posts, saw timber, and material for farm improvements. The forest management plan must integrate with the county plan.

Statistics show that the income of Alcona County farmers is lower than that of farmers in almost all the other counties in the state. To augment their income efforts are being made to secure better farm practices, increase the cleared land on each farm, improve pastures, and provide supplemental earnings by the harvesting of the timber crop. To assist in the development of the local timber economy the Forest Service sponsored the Au Sable Forest Products Cooperative Association, a coöperative engaged in marketing forest products. It was organized with the help of the Extension Service and financed by the Farm Security Administration. Attention is here called to the three bureaus of the Department of Agriculture that work jointly on this enterprise. If intensive county land-use planning has obtained no result other than that of bringing various governmental units together to work for a common purpose, it has achieved a highly desirable objective.

The coöperative is a marketing association that secures contracts for forest products produced by the members, finances stumpage when necessary, makes advance payments to members when they have forest products cut in the woods, and arranges for the trucking and loading on cars if a member does not have a truck.

Field representatives of the Forest Service (rangers and scalers) give the operators instructions concerning specifications for various forest products so that they will be marketable, advises them on the proper tools to use to increase production, such as one-man Swedish bucksaws instead of the conventional two-man saw, and tells them how to lay out strip roads and pile their products so that the trucks can pick them up. In this way the association aids in solving the small producers' problems of marketing, financing, and operating procedure. About fifty farmers are active members of the association and are supplementing their farm income by harvesting forest products, which are sold through the coöperative.

Alcona County's intensive plan is not sufficiently complete to enable one to prepare a report covering all uses. The initial planning has been to classify lands for farming, pasture, recreation, hunting,

and various public uses. The next step is to correlate the use of the lands classified to meet as well as possible the needs of the people. This is the action field in which the various bureaus of the Department of Agriculture must participate in conjunction with the local governmental units if the benefits of the plan are to be realized.

The United States Forest Service can and will assist (1) by adjusting its program so as to acquire by exchange or purchase those lands not suited to agriculture or higher private use, (2) by exchanging agricultural lands now in government ownership for non-agricultural lands as the need arises, (3) by providing a sufficient supply of forest products to meet the needs of agriculture and other local enterprises in preference to supplying outside industry, (4) by assisting in the development of methods whereby supplemental incomes can be secured by harvesting timber products and marketing them through coöperatives such as the Au Sable Forest Products Cooperative Association, (5) by providing employment in the development and protection of the forest, and (6) by giving full coöperation to other agencies in placing the plan into effect.

United States Forest Service
Huron National Forest
East Tawas, Michigan

HUNTER EXPENDITURES IN CHEBOYGAN COUNTY, MICHIGAN, DURING THE SEASONS OF 1939–40, 1940–41, AND 1941–42

JULIAN GRIGGS

AN INDEX of the value of game in the northern Michigan cutover area is afforded by the amount of money spent and earned in connection with hunting. A study that would measure this value in terms of sales of goods and services to hunters would be of aid in planning for the game resource and in expanding the income to be derived from it. The present paper is an analysis of data that were collected in Cheboygan County,[1] an area of 725 square miles in the northern part of the Lower Peninsula. The principal population centers are Cheboygan, with 5,600 inhabitants, Mackinaw City, with 900, and the villages of Indian River, Topinabee, Tower, and Wolverine. The transportation system is good. Three state highways pass through the county, and another touches it at Mackinaw City. Between it and the Upper Peninsula the State Highway Department operates a ferry service that connects with these automobile arteries after they have converged at Mackinaw City.

Because of many variables the selection of a county in which expenses of hunters might be regarded as typical proved difficult. Though no single county can give an overall picture, Cheboygan County was thought to be a fairly representative hunting area. Although the number of sportsmen hunting there was slightly less than the average number in the northern counties in the Lower Peninsula, it was a little above the average for counties in the Upper Peninsula. The percentage of hunters who were successful in killing a deer was less than in many Lower Peninsula areas, but the average kill of grouse and snowshoe hares was greater. Expenses are heaviest in

[1] This work was sponsored by the Game Division of the Conservation Department of the State of Michigan and by the School of Forestry and Conservation of the University of Michigan.

localities where good hunting areas are situated close to towns. Since in Cheboygan County the best hunting is at a considerable distance from population centers, the expenses of those hunting in the county are less than might normally be expected. It is felt, however, that this deficit is offset by the income derived from the abnormally large number of hunters who pass through the county to take the ferry to the Upper Peninsula.

THE METHOD OF INVESTIGATION

The interviewing technique employed was similar to that used by Gordon to compute the expenditures of hunters in Washtenaw County, Michigan.[2] Sportsmen were questioned by the writer, and data on their Cheboygan County hunting expenses were recorded on form sheets. Some were given questionnaires, together with self-addressed stamped envelopes, to be filled in later. In this way further information was secured after the interviews. Often proprietors of cabins were able to itemize expenditures of sportsmen who came from other counties but were not available for interrogation.

In each northern county expenses are incurred by hunters who pass through it en route to their favorite hunting grounds as well as by those who hunt within it.[3] In the investigation in Cheboygan County sportsmen were classified as residents of the county and as nonresidents. A distinction was made between nonresidents who hunted in the county and those who merely drove through it during their trips after game.

Types of goods and services purchased by the different groups of sportsmen varied. Expenditures for travel by car and for ammunition and clothing were made by hunters in each of the categories, but only the nonresidents who hunted in the area paid for guide services. Some nonresidents and some residents bought materials and labor for building or renovating cabins, but, of course, none of the sportsmen who crossed Cheboygan County without

[2] Gordon, Seth, Jr., "A Sampling Technique for the Determination of Hunters' Activities and the Economics Thereof," *Journal of Wildlife Management*, 5 (1941): 260–278.

[3] Expenditures of those who travel through Cheboygan are atypical with respect to state ferry fees (which are peculiar to that county and to one other) because they benefit these areas by providing employment for the local population. Inclusion of these fees (Table III), however, probably renders the total representative by offsetting the abnormally low expense of sportsmen who hunt in the Pigeon River and Black Lake State Forests.

stopping to hunt spent money for such items. In figuring the expenses of those who lived within the area studied the cost of board and lodging and of beverages and amusements was not included because such outlays would have been made had they done no hunting.

In computing expenses the schedule forms and questionnaires of the group of hunters interviewed were analyzed in order to get the average sum. This amount was then multiplied by the total number who hunted as a means of learning what they all spent. The methods of finding the number of hunters in the various groups were different. The number of county residents who hunted was secured by consulting the license records and by questioning those who hunted legally without a license, that is, farmers who sought small game on their own enclosed lands. The number of nonresidents who hunted in the county was computed from interviews, from questions asked of those who lodged sportsmen, from information procured in local papers, and from field observation. Michigan state ferry statistics were used in conjunction with interviews to find the number of sportsmen who drove through Cheboygan County on trips after game.

The group of sportsmen questioned was typical of the hunters as a whole. Representativeness was determined through the criteria of geographical distribution, age, and occupation. Where none were available, a test based on the standard deviation was made. Because of the small number of interviews the accuracy of expenses listed for nonresident duck and rabbit hunters cannot be assured. The reliability of all other data is high.

EXPENSES OF RESIDENTS

The average annual expense of Cheboygan County hunters within and outside the county during the seasons of 1939–40 and 1940–41 was $18.98, as is shown in Table I. Of this amount 85 per cent was expended within the county. The 2,350 sportsmen paid out a total of $44,600. Travel by car cost more than any other single item, and outlays for buying and caring for hunting dogs were the next highest items. Most hunters spent more for ammunition and for clothing and miscellaneous purchases than they did for guns. About 12 per cent of the purchases within the county were made in rural areas where dogs, second-hand guns, and camp improvements were the principal items.

TABLE I

ANNUAL HUNTING EXPENSES OF CHEBOYGAN COUNTY RESIDENTS FOR THE SEASONS OF 1939–40 AND 1940–41 *

Items	Number of hunters interviewed	Expenses in the county		Expenses outside the county	
		Average expense per hunter	Total spent by hunters	Average expense per hunter	Total spent by hunters
Travel by car	190	$4.21	$9,900	$0.87	$2,040
Hunting dogs	630	4.08	9,590	0.43	1,000
Ammunition	810	2.71	6,380	0.18	420
Clothing and miscellaneous items	810	2.49	5,840	0.21	500
Guns	810	2.34	5,500	0.73	1,710
Camp improvements .	810	0.26	620	0.47	1,100
Totals	...	$16.09	$37,830	$2.89	$6,770

* 2,350 was the average yearly number of hunters for the period.

EXPENSES OF NONRESIDENTS OF THE COUNTY

More nonresidents than residents hunted in the county, and expenses incurred by the sportsmen from outside markedly improved the fall business conditions. The number of deer hunters was about twice the number of hunters of all other game species combined. Therefore the large-game season, November 15 to 30, was a period of intensive hunter spending.

In Table II the expenses incurred in hunting the four principal types of game are listed. The items that made up these expenses were camp improvements, beverages and amusements, board and lodging, travel by car, groceries, guide service, guns, ammunition, dogs, clothing, and miscellaneous purchases. Amounts spent by individuals depended somewhat on their annual incomes and on the number of days they hunted. Most grouse hunters earned higher salaries than the sportsmen in search of large game, and they expended 67 per cent more on the average. Ducks and snowshoe hares were hunted for shorter periods than other game, and hence costs were lower. As a rule, the duck hunter spent more than the rabbit hunter.

TABLE II

EXPENSES OF NONRESIDENT HUNTERS WHO STAYED IN CHEBOYGAN COUNTY AT LEAST ONE DAY AND ONE NIGHT DURING THE 1940–41 SEASON *

Game hunted	Number of hunters inter-viewed	Number of hunters	Average expense per hunter	Total spent by hunters
Snowshoe hares	8	40	$10.00	$ 400
Ducks	8	80	15.00	1,200
Grouse	55	275	22.54	6,200
Deer	330	830	13.50	11,170
Total	...	...	...	$18,970

* The expenses of those who hunted but who did not stay overnight are not included. Estimates based on field observations indicate that there were about 2,500 of these hunters and that they spent about $3,000 during the season. Thus expenses of all nonresidents who hunted in Cheboygan County amounted to $21,970.

Proportional costs to hunters for the several items varied with different types of sportsmen. Thus the large-game hunters spent 32 per cent of the total of $11,170 for camp improvements, 26 per cent for beverages and amusements, 24 per cent for board and lodging, 10 per cent for travel by car and smaller percentages for other items. Grouse hunters spent proportionally more for board, lodging, and travel by car, and less for camp improvements and beverages and amusements. The percentages of their total costs for these purchases were 26 for camp improvements, 14 for beverages and amusements, 27 for board and lodging, and 13 for travel.

EXPENSES OF HUNTERS WHO PASSED THROUGH CHEBOYGAN COUNTY EN ROUTE TO HUNTING AREAS ELSEWHERE

Only a few small-game hunters traveled through the county on their way to hunt elsewhere, but many sportsmen in search of large game did so. Most of them came north just before the deer season opened, and in 1940 many were caught in the November blizzard that caused interruption of the state ferry service for more than twenty-four hours. It forced sportsmen to delay at Mackinaw City, where their expenses were high while they were awaiting passage to St. Ignace. In 1941, however, the weather was mild and ferry serv-

ice continuous, so that no extra expenses were incurred. Table III shows that on the average hunters spent only 74 per cent as much as they had done in 1940, and that beverages and amusements cost them only 47 per cent as much. The total expenses of hunters were nearly as great as they were in 1940, however, because the number crossing the Mackinac Straits was 37 per cent larger.

TABLE III

EXPENSES OF HUNTERS IN PASSING THROUGH CHEBOYGAN COUNTY *

Items	Number of hunters interviewed		Expenses	
	1940	1941	1940	1941
Travel by car	1,983	1,159	$17,440	$17,680
State ferry fees	1,108	1,159	15,880	21,200
Food and lodging	1,983	1,159	14,640	9,090
Beverages and amusements	1,983	1,159	3,910	2,036
Camp supplies, ammunition, clothing, and miscellaneous items	1,108	1,159	845	890
Totals	...	...	$52,715	$50,896

* There were 20,700 hunters in this group in 1940 and 27,000 in 1941.

THE VALUE OF HUNTING TO THE COUNTY

One of the major problems of the trade with tourists arises from the shortness of the summer recreation period. Persons who cater to these seasonal visitors must make their living during a few months of the year or else supplement their income by other occupation in the winter and spring months. This condition is alleviated by utilization of the game resource, which attracts visitors who would otherwise come to the county only in the summer.

During the hunting seasons in question the average annual expenditures of hunters in the county amounted to $112,000, of which 66 per cent was brought in by sportsmen from other places. The remaining 34 per cent was spent by residents.

A LOOK AHEAD

The study indicates that it may be possible to expand incomes from the game resource indirectly through the sale of more goods

and services to hunters. They spend surprisingly little in rural areas, despite the fact that many of them room and board with farmers during their stay. Residents of the county might sell sportsmen more farm and other products. Articles that carry the aroma of the Northland might have an appeal to hunters. Maple sugar and appetizing preserves could be offered for sale.

Attractive wooden ornaments and objects that might serve some useful purpose can be made by hand with a minimum of tools. Tests by the writer have indicated that packboards with canvas packsacks attached are easy to construct. Such a beginning might lead to the establishment of a small woodworking plant capable of making things that sportsmen would buy. Experiments have shown that aspen, often considered a weed species, can be employed more than it is at present. Investigation at the University of Michigan is beginning to reveal that practical aspen products can be made locally with simple equipment.

The situation is one that merits further attention, and the study is being continued in an effort to find means of enabling residents to make better provision for sportsmen and thus increase the income derived from the game resource.

University of Michigan

PARTIAL CUTTING IN BLACK SPRUCE IN THE LAKE STATES *

RUSSELL K. LeBARRON

IMPORTANCE OF SPRUCE TIMBER

ONE of the more important remaining softwood timber resources of the Lake States is spruce, because of its inherent suitability for the manufacture of paper and because of the large volume obtainable, nearly seventeen million cords (2). The available statistics do not show the proportion by species, but black spruce (*Picea mariana*) undoubtedly far exceeds white spruce (*Picea glauca*) in both volume standing and amount cut.

Although extensive black-spruce stands occur on upland mainly because of this tree's peculiar seeding habits, which enable it to reseed after forest fires in much the same manner as jack pine (5), it is particularly at home in swamps. If one takes into account both spruce swamps and "spruce-fir" upland, nearly eight million acres in the Lake States are suited to the growth of black spruce. This amount is exclusive of muskeg and "Christmas tree" bogs, where the trees never attain merchantable size for pulpwood.

Some foresters have been inclined to disparage the management possibilities of black spruce because of its slow growth. It is true that it is a slow-growing species, and on the wetter bogs the trees never become large enough for pulpwood. Yet, if such nonproductive sites are eliminated from consideration, its mean annual growth, as computed from yield tables, is only about one third less than that of jack pine, which is ordinarily regarded as a fairly rapid-growing species (3–4). When one bears in mind that black spruce commonly brings over twice as much stumpage as jack pine, its true value becomes clearer.

Previous to about 1930 almost all logging of black spruce was by

* Assistance in computations was furnished by personnel of the Work Projects Administration, Official Project 165–2–171–488, Sponsor, Lake States Forest Experiment Station.

clear-cutting. Loggers favored this method for economic reasons, and even many foresters believed that clear-cutting was necessary because of the reputation spruce has for lack of wind-firmness. In 1931 the Lake States Forest Experiment Station made a survey of cutover areas in northeastern Minnesota which showed that black-spruce swamps, when clear-cut, had generally reproduced rather well and that residual trees overlooked by the loggers had increased their rate of growth considerably (1). Since that time numerous studies have been undertaken by the Experiment Station to learn the reaction of black spruce to various types of cutting, its seeding habits, conditions essential for its regeneration, and its ecological requirements. The material presented in this paper summarizes the phases of this project having direct application to the possibilities of partial cutting.

CUTTING EXPERIMENTS

During 1934 and 1935 two series of cutting experiments in black spruce were initiated in northeastern Minnesota. One dealt with a typical even-aged, 65-year-old upland stand of fire origin growing on a shallow loamy soil overlying a ledge rock formation. The timber contained a small percentage of jack pine and aspen, and a scattering of paper birch, red pine, and eastern white pine. The volume ranged from 25 to 35 cords[1] per acre in various portions of the area. The site quality is about medium. Owing to the heavy spruce overstory there was practically no low vegetation except hypnum moss (*Calliergon schreberi*) that formed a continuous carpet over the ground much like that in dense swamp forests. The other series of plots was situated in two adjoining bogs, where the depth of the peat ranged from one half to two feet. Here there was considerable variation in age, with the older trees as much as 180 years old. The volume amounted to 18 to 25 cords per acre. The site quality is below the "poor" grade given in a black-spruce yield table (4). The principal forms of low vegetation were hypnum moss, sphagnum mosses, and Labrador tea.

Three methods of cutting were applied in both the upland and the swamp series: (1) clear-cutting, (2) partial cutting, and (3) clear-cutting in alternate 100-foot strips. In addition, uncut plots were reserved for comparison. In the upland partial cutting 25 per cent

[1] All trees over 3.5 inches d.b.h.

of the volume was removed. The cut was composed of the larger trees and included nearly all the jack pine. This resulted in a residual stand of excellent appearance. In the swamp partial cutting 40 per cent of the volume was removed. In places where there was a fair distribution of size classes the cutting left a good residual stand, but where the trees were nearly all larger, and fewer, the remaining stand was open. The 100-foot alternate strip cutting was laid out with the strips running east and west, roughly parallel with the prevailing winds, and the ends of the strips were left closed. In an earlier test reported by Shantz-Hansen (6) 66-foot strips running north and south had suffered from wind. Hence in planning the present experiment it was decided to make the strips wider and parallel with the prevailing winds in an attempt to lessen damage of the type described by Shantz-Hansen. Since only trees large enough for pulpwood were utilized, a good many small trees were left in the cut strips after logging was completed.

RESULTS

Upland Plots

The trees on the upland plots were remeasured after seven growing seasons. It was found that the uncut plot had made a net gain in volume of 7 per cent, although there had been a 4 per cent decrease in the number of trees (Table I). All other plots had suffered serious losses. The partial cutting lost 27 per cent of the trees and 19 per cent of the volume; the clear-cut strips, 80 per cent of the trees and 69 per cent of the volume; and the uncut strips, 31 per cent of the trees and 24 per cent of the volume. The residual trees in the clear-cut strips were largely suppressed individuals below merchantable size, so that heavy losses there had been expected, but the damage to the uncut strips and partial cutting was disappointing.

A study of the causes of mortality offers some rather significant information. On the uncut plot 28 per cent of the mortality was caused by windbreak and windthrow. On the partial cutting wind damage accounted for 37 per cent. On the clear-cut strips wind caused 76 per cent of the losses and on the uncut strips 54 per cent. It is apparent that on the strip cuttings wind was a sufficiently important hazard practically to disqualify the method for use on exposed sites, regardless of the extent of injury from other causes. It should be noted that in the partial cutting wind caused only about one

third of the losses, and hence it was much less important. The cause of the remaining 63 per cent of the mortality was not diagnosed satisfactorily, but it was almost certainly related to the extreme drought conditions of 1934 and 1936 and to the generally subnormal precipitation which prevailed over northeastern Minnesota for several years. The upland partial cutting test should therefore be rated as indecisive with respect to postcutting mortality. Further tests should be made of the utility of partial cuttings in upland spruce during years of normal or near-normal precipitation, particularly with somewhat younger stands.

TABLE I

NET CHANGES IN VOLUME AND NUMBER OF TREES IN UPLAND PLOTS DURING THE FIRST SEVEN YEARS AFTER CUTTING

Cutting method	Volume per acre		Trees per acre	
	Cords	Percentage	Number	Percentage
Uncut plot	+ 2.2	+ 7	− 28	− 4
Partial cutting	− 4.4	− 19	− 171	− 27
Clear-cut strips	− 4.1	− 69	− 210	− 80
Uncut strips	− 8.2	− 24	− 246	− 31

Swamp Plots

The trees on the swamp plots were remeasured after six growing seasons. In general, the results were much more satisfactory than those on the upland (Table II). Volume increases ranged from 7 to 16 per cent, although there were slight decreases in the number of trees. The relatively large growth on the uncut plot (3 cords in 6 years) is undoubtedly a temporary fluctuation, and over a longer period the volume on this overmature stand should remain essentially constant. The gains on the partial cutting may be taken as real and significant because the most overmature and decrepit trees had been removed. The growth on this plot, 1.7 cords in 6 years, is not impressive, but considering the very low natural productivity of the site it probably represents about all the growth that can be expected after the initial improvement cutting. It is believed that better-quality swamps will give proportionately better results. Recent experimental cuttings made in coöperation with the Minnesota Forest

Service near Big Falls, Minnesota, should provide information on this point after a few more years (Pl. I).

In one of the partial cutting plots there is an excellent distribution of size classes that should insure continuous periodic cuttings of perhaps 5 cords every 20 years. The other sample of partial cutting has less favorable distribution of sizes, and may reach a hiatus after one or two additional cuts have been removed. But even here it is believed the partial cutting will have proved helpful, first, by getting some additional growth on the present stand of timber, and, secondly, by greatly shortening the period between the removal of the last of the present crop and the first of the next crop.

TABLE II

NET CHANGES IN VOLUME AND NUMBER OF TREES IN SWAMP PLOTS DURING THE FIRST SIX YEARS AFTER CUTTING

Cutting method	Volume per acre		Trees per acre	
	Cords	Percentage	Number	Percentage
Uncut plot	+ 3.0	+ 12	− 30	− 4
Partial cutting	+ 1.7	+ 16	− 10	− 2
Clear-cut strips	+ 0.2	+ 7	− 25	− 14
Uncut strips	+ 2.1	+ 9	− 35	− 6

The 40 per cent initial cutting (about eight cords per acre) was too heavy to obtain the highest rate of growth, since it depleted the growing stock considerably. It is likely that a 25 per cent or five-cord cut would have given slightly better results. In the present instance it was believed necessary to take out eight cords, partly to satisfy the demands of pulp cutters and partly to insure removal of all the most decrepit trees. Subsequent experience has taught us, however, that somewhat lighter cuts are adequate for the initial improvement cutting. Furthermore, loggers are being educated rather rapidly to lighter cuts on managed forests, so that today cuts of four or five cords of spruce per acre will find buyers in accessible localities when pulpwood prices are good.

None of the plots in the swamp series experienced severe mortality except the clear-cut strips, where only a scattering of small suppressed trees was left (Table III). Even there the mortality was not so serious as in the upland strip cuttings. About half of the losses

were caused by uprooting and breakage, the proportion being nearly the same for all plots. It has been observed on a number of recent timber sales on the national forests that light cuttings in spruce swamps have not suffered excessive mortality from wind or other cause. Preliminary results from the new Big Falls cutting experiments show the same thing. Swamp black spruce seems to be sufficiently windfirm to endure thinnings of 25 to 40 per cent.

TABLE III

Mortality Losses in Volume and Number of Trees in Swamp Plots during the First Six Years after Cutting

Method of cutting	Volume per acre		Trees per acre	
	Cords	Percentage	Number	Percentage
Uncut plot	1.3	5	46	6
Partial cutting	1.0	9	32	7
Clear-cut strips	0.9	30	55	30
Uncut strips	1.6	7	50	8

Partial cuttings of the type being discussed should be regarded as only an initial improvement cutting designed to convert wild natural stands to managed forests. They are not comparable with formal silvicultural systems, which are usually intended to be repeated again and again. Many of our wild forests will require two or three improvement cuttings before they commence to display their highest productivity. The yield from thrifty, managed forests and the best silvicultural practices for such forests cannot be determined until existing forests have been improved by judicious cutting. In the meantime the general rules to be followed are:

1. Maintain a large volume of growing stock by refraining from too heavy and too frequent cutting.
2. Improve thrift and growth by removing the mature, slow-growing, and less windfirm trees.
3. Strive for better distribution of size and age classes in order to provide growing stock for future cuttings.

SELECTION OF TREES TO CUT AND TO LEAVE

An important problem of partial cutting is how to select the trees to cut and those to leave. Obviously it is desirable to leave the

younger or more vigorous trees, but can they be identified easily and accurately? There is some evidence that vigor in black spruce can be recognized with a fair degree of certainty. To determine whether vigor can be judged by external characteristics increment cores were extracted from 84 trees, chosen at random in a swamp stand, which had been classified as "progressive," "stable," and "regressive." The diameter growth by vigor classes, shown in Table IV, indicates

TABLE IV

DIAMETER GROWTH FOR THE PERIOD 1931–40 BY VIGOR AND ONE-INCH D.B.H. CLASSES*

D.b.h. class in inches	Average d.b.h. growth in inches, 1931–40, by vigor classes		
	Progressive	Stable	Regressive
4	0.71	0.58	0.24
5	1.02	0.63	0.22
6	0.71	0.75	0.20
7	0.68	0.51	0.29
8	...	0.54	...
9	0.79	0.59	0.25
10	...	...	0.80
11	...	0.74	...
Average	0.78	0.62	0.33

* Basis 84 trees.

that vigor was estimated accurately. In general the trees ranked as "progressive" grew the best, and the "regressives" the poorest. The comparatively fast growth among the stable and regressive trees in the 10- and 11-inch diameter classes may need some explanation. Although they had a good record for past growth, these trees are now showing signs of decadence and will probably die soon. Further analysis of the borings revealed that, for the lower diameter classes, the less vigorous trees tended to be older (Table V).

In classifying the trees by vigor classes progressive trees were those judged to be thrifty and likely to maintain a good rate of growth during the near future; regressive ones were those which appeared to be growing slowly or were likely to do poorly in the future; and stable trees were the ones intermediate between the progressive

TABLE V

AVERAGE TOTAL AGE IN RELATION TO VIGOR CLASS AND DIAMETER CLASS

Diameter class in inches	Average age in years by vigor classes		
	Progressive	Stable	Regressive
4	66	91	118
5	85	110	140
6	100	114	109
7	136	132	151
8	...	130	...
9	142	134	146
10	...	...	(?) *
11	...	145	...

* Core too rotten to permit reasonably accurate count.

and the regressive trees. Assignment of the trees to these vigor classes was based largely upon the following characteristics:

1. *Dead tip (upper 1- to 5-foot portion of the crown).* — A dead tip is believed to indicate a distinctly unthrifty condition; the tree is likely to die soon.

2. *Length and density of crown.* — A long and dense crown is evidence of rapid growth.

3. *Appearance of bark.* — Gray, shaggy bark is a characteristic of old trees (usually over 100 or 125 years). Trees with this kind of bark are generally slow growers. Dark bark with small tightly attached scales is associated with younger and more vigorous trees. Cracks in the bark to accommodate larger diameters are evidence of growth.

It seems evident from the data on growth in relation to vigor and size classes (Tables IV–V) that diameter-limit cutting rules or the very similar "stick-limit" cutting, in which trees having more than a specified number of sticks are cut, will not make the most of the possibilities for removing the slow growers and leaving the fast growers. Such rules allow the cutting of many promising trees and prevent the cutting of poor ones. Furthermore, it has been found difficult to get pulpwood cutters to adhere to diameter-limit or stick-limit rules. They are paid according to the number of sticks, and hence they have a financial incentive to cut as many pieces as possible

with a minimum amount of strip-road construction. For the best results the trees should be marked in advance of cutting. Marking is not so expensive as might be expected. It has been reported by H. L. Sundling, of the United States Forest Service, that in recent years many thousands of cords of spruce have been marked in partial cuttings on the Superior National Forest at a cost of about 10 cents per cord. Such a cost, which amounts to from 50 cents to $1.00 per acre, depending upon the cut, is certainly a modest expense for insuring continued productivity of the forest.

ROTATION AGE

Some consideration has been given to the problem of the right age at which to cut swamp-grown black spruce. The study at Big Falls, Minnesota, mentioned previously, included the collecting of increment cores near the ground level to investigate the development of wood decay in relation to age. Stump cores in trees less than 85 years old contained no actual rot, although some stain was present; 34 per cent of the trees from 86 to 105 years in age showed advanced decay, 41 per cent in the 106- to 125-year class, 47 per cent in the 126- to 145-year class, and 71 per cent among trees over 145 years old. Butt rot in spruce is not a serious factor in loss of wood, because the decay seldom extends upward more than two or three feet, but it does make the trees susceptible to breakage by the wind. Before attempting to generalize on the relation of decay to age it will be necessary to gather samples in other localities, but in this instance rot appeared to begin weakening the trees appreciably at about 120 years. In upland black spruce butt rot begins considerably earlier. On such sites in northeastern Minnesota 60–70-year-old trees with decayed bases that have been broken over by winds are common.

THE PROBLEM OF DECADENT STANDS

The virgin black-spruce swamp forests of the Lake States include a large number of greatly overmature stands that represent a difficult problem for conversion to managed stands. The timber in them is low in stocking, and in many of them there is a decided scarcity of seedlings and saplings. The problem is further complicated by the frequent occurrence of a heavy growth of Labrador tea, which seriously interferes with reseeding. The situation is analogous to that in many overmature upland types, such as white pine, in which dense

growth of shrubs retards reproduction. Under natural conditions poorly stocked overmature black-spruce swamps would probably be reproduced eventually through the intervention of fires, which, by burning off the litter and shrubby growth, provide a good seedbed. Regenerating spruce swamps by burning is not directly applicable on managed forests, however. Burning before logging would destroy or seriously degrade much of the merchantable pulpwood and, further, could be carried out successfully only during hazardous fire weather, because forested swamps do not burn easily. A fire after logging is no help to reproduction because it destroys the seed scattered over the ground or enclosed in the cones lying in the slash. The question of proper silvicultural practice for decadent spruce swamps is, therefore, still an open one. They are not well suited to the partial cutting method recommended in this paper.

REGENERATION

In most kinds of stands it does not appear to be difficult to obtain satisfactory regeneration after light cuttings. Six years after cutting in the swamp plots in northeastern Minnesota, for which the growth data have been reported, different parts of the area had from 900 to 5,600 black-spruce seedlings and saplings up to 3.5 inches d.b.h. Much of this stocking was advance reproduction of seedlings and layers that were present before logging. Regeneration of partial cuttings is simplified by the continuing seed supply, which eliminates the necessity of getting reproduction at once. On the other hand, clear cuttings must be restocked before or at the time of logging if the land is to be maintained at a high level of production.

Some attention has been given to improving reproduction by disposing of logging slash in various ways. Repeated observations have shown that heavy accumulations of spruce tops, limbs, and peeling bark not only smother seedlings already present but also prevent the establishment of new ones. As soon as spruce limbs dry out, the needles fall, forming a thick dry carpet that remains intact, sometimes for several years, until it is overgrown with sphagnum moss. The obvious ways of preventing this condition are either by concentrating the slash on as small an area as possible or by burning it in piles. In a test conducted by the Superior National Forest on a moderately heavy partial cutting near Grand Marais, Minnesota, the results three years after logging were as follows:

Slash-disposal method	*Number of black-spruce seedlings per acre*
No disposal	1,133
Lop and scatter.	1,983
Pile	2,867
Pile and burn	2,250

The differences in seedling establishment are not striking, but they do show a trend that is in general agreement with the theory. Larger differences would probably occur in clear cuttings, where the slash accumulation is heavier.

Partial cuttings in upland black spruce seem to restock satisfactorily, but there is a decided change in species composition. After several years the upland partial cutting described previously had 1,000 black-spruce seedlings, 520 aspen suckers, 360 paper-birch seedlings, and 120 mixed jack-pine and white-pine seedlings per acre. No balsam fir seed trees were present; otherwise this species would have reproduced vigorously. It is believed that the several species named above will make a silviculturally desirable mixture in which black spruce can be maintained as a reasonably important component by the use of discrimination in future stand-improvement cuttings.

SUMMARY AND CONCLUSIONS

The studies and observations on the effects of partial cutting in black spruce reported in this paper suggest the following conclusions:

1. Swamp forests in reasonably thrifty condition are suited to partial cuttings in which 25 to 40 per cent of the volume can be removed. The cut should consist of decadent and slower-growing trees.

2. The relative vigor of individual trees can be judged with a fair degree of accuracy by the condition of the crown and the appearance of the bark, which permits rapid selection of the correct trees to remove in partial cutting.

3. Regeneration in partially cut stands is likely to be satisfactory, although it can be improved by reducing the area covered with slash and bark, as by compact piling or by piling and burning.

4. Greatly overmature, open stands, with a heavy low cover of Labrador tea, are not suited to partial cutting. The correct silvicultural management for such stands remains a problem.

5. Partial cutting in 65-year-old upland black spruce resulted in very serious losses of volume. The volume of the trees which died as a consequence of injury by drought and wind exceeded the gain in volume made by the surviving trees. Further tests of partial cutting should be made in younger stands during periods of more nearly normal precipitation.

6. Upland stands are usually fire types which, after cutting, tend to convert to mixed forests containing a variety of species. It should be possible, however, to maintain black spruce as an important component of the stand by liberation and improvement cuttings.

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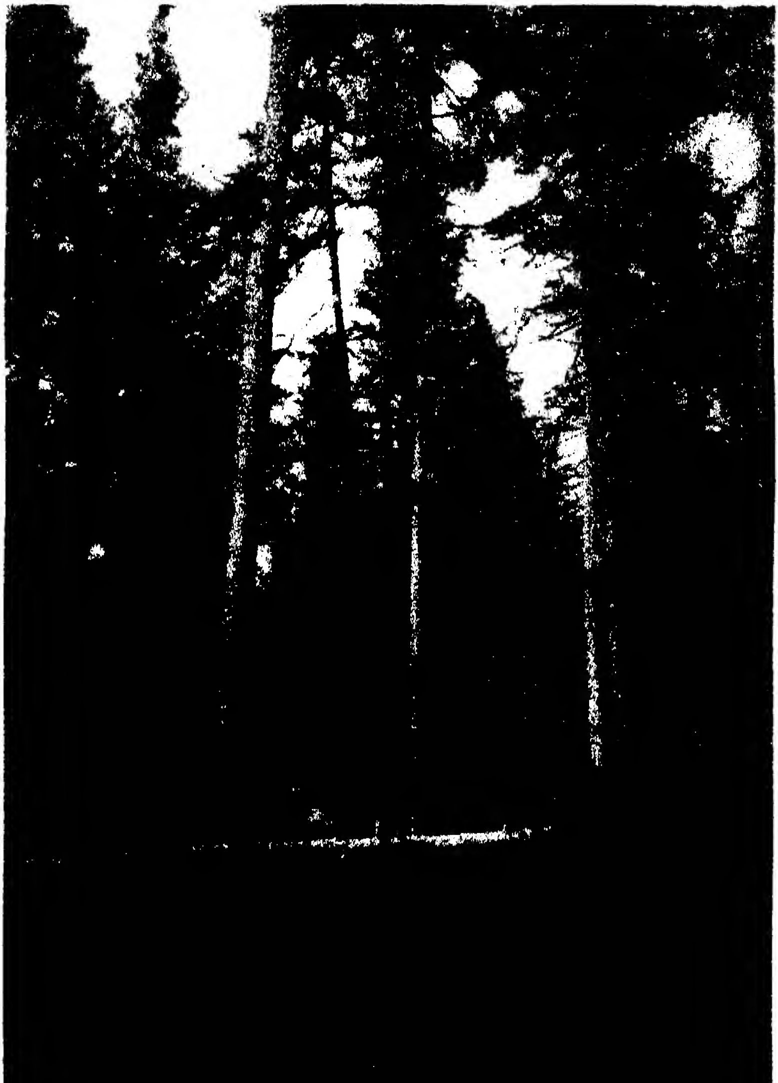

Black spruce swamp forest at Big Falls, Minnesota. When composed of trees of mixed sizes and ages such forests are well suited to partial cutting. The down tree in the foreground is evidence of approaching decadence

MANAGING FARM WOODLANDS OF THE OAK-HICKORY TYPE

ALLEN FRANK MONROE

INTRODUCTION

BECAUSE of lack of pertinent data foresters and others interested in the oak-hickory farm woodlands in southern Michigan have found it difficult to evaluate their utilization possibilities under management. It is easier to decide on a system of management for the more normally stocked northern hardwoods of Upper Michigan, where grazing has not been commonly practiced. Basal areas of 140 square feet per acre may be expected in the northern hardwoods, but the inventory in most of the oak-hickory type woodlands of Lower Michigan shows only a fraction of this area. The data gathered in these woodlands indicate an average basal area of 40 to 50 square feet per acre; areas of 80 square feet occur rarely.

Management of the average 18–20-acre woodland necessitates the solution of many problems that vary considerably with each farm. Woodland-management plans, in order to be effective, should form a part of the entire farm-management plan. However, before the integration of farm woodlands within the general management plan of the operating units can be accomplished, it is necessary to determine the factors bearing upon the management of the farm forests.

INVENTORIES AND CONDITIONS OF THE OAK-HICKORY FARM WOODLAND

An inventory of the timber found on 1058.3 acres representing 45 farm woodlands well distributed in northeastern Livingston and southwestern Genesee counties is given in Table I.

The poorly stocked woodlands carry a high percentage of aspen, sassafras, serviceberry, ironwood, and blue beech. Pasturing and overcutting have contributed materially to the high frequency of these inferior species.

Table I shows that only 3.7 per cent of the total number of trees

TABLE I

Distribution of Tree Species on Forty-Five Farm Woodlands

1058.3 acres

Species		Number of trees: Diameter in inches 2–6	7–14	15+	Total	Percentage	Approximate number of standard cords. All trees	Approximate merchantable board feet. Trees 15 inches and larger d.b.h.
Red oak. . . .	Main timber species	22,712	21,245	2,905	46,862	26.5	9,166.7	795,910
Hickory. . . .		26,448	8,387	458	35,293	20.0	2,312.1	88,390
White oak. .		22,867	10,063	1,296	34,226	19.4	3,688.6	294,893
Maple.		9,093	4,822	441	14,356	8.1	1,481.1	124,151
Ash		7,727	3,435	191	11,353	6.4	1,164.1	43,177
Elm		6,347	2,583	504	9,434	5.3	1,396.5	143,988
Cherry		4,899	1,405	103	6,407	3.6	412.7	20,732
Aspen		3,027	1,281	8	4,316	2.4	231.7	. . .
Basswood . .		2,306	1,304	197	3,807	2.2	536.2	67,014
Swamp oak .		1,315	1,061	279	2,655	1.5	451.1	81,241
Sassafras . . .	Species of secondary importance	2,049	145	1	2,195		35.5	. . .
Serviceberry		1,678	19	. . .	1,697		31.6	. . .
Ironwood . . .		1,473	172	. . .	1,645		49.5	. . .
Yellow birch		454	147	1	602		50.2	. . .
Blue beech .		510	. . .	. . .	510		7.8	. . .
Beech		234	180	25	439		32.0	5,185
Willow		63	104	6	173		22.6	. . .
Tamarack . .		51	97	7	155		45.4	880
Black walnut		35	93	24	152		31.8	5,380
Black gum . .		74	44	24	142	4.6	9.3	1,697
Butternut . .		64	46	1	111		6.0	110
Black locust.		61	11	. . .	72		2.7	. . .
White pine .		17	50	. . .	67		5.4	. . .
Dogwood . . .		44	. . .	. . .	44		0.3	. . .
Tulip		1	8	17	26		24.6	12,062
White birch .		13	4	. . .	17		0.5	. . .
White poplar		2	4	3	9		3.5	290
Red cedar . .		6	. . .	. . .	6		0.1	. . .
Mulberry . . .		3	. . .	. . .	3		. . .	. . .
Total		113,573	56,710	6,491	176,774	100.0	21,199.6	1,685,100
Percentage. .		64.2	32.1	3.7		100.0		
Per acre		107	54	6	167		20.0	1,592

Approximately 46 per cent of the red oak consists of black oak and Hill's oak; 75 per cent of the maple is soft maple; and 85 per cent of the ash is white ash. Burr oak is classed with white oak. Swamp oak is given separately, since it has a considerable local use for fence posts.

measure 15 inches or over in diameter. This represents 1,592 board feet per acre. According to the data collected, the amount of timber in saw logs grown in the average farm woodland is sufficient to cover only one half of the farm's lumber needs. It is apparent from these facts that the marketing of timber from such woodlands is not feasible. Nevertheless, a movement of a considerable volume of saw logs was observed out of the territory studied and to the local mills. Much of this timber is cut from the 10- to 15-inch diameter class,

TABLE II

DISTRIBUTION OF BASAL AREA PER ACRE BY SPECIES AND SIZE CLASS

1058.3 acres of woodland survey

Species	Diameter in inches			Total	Percentage
	2–6	7–14	15 +		
	Basal area per acre in square feet				
Red oak	2.9	10.4	4.5	17.8	32.3
Hickory	2.4	5.6	0.8	8.8	16.0
White oak	2.9	5.4	2.2	10.5	19.1
Maple	1.2	2.4	0.8	4.4	8.0
Ash	1.2	1.9	0.2	3.3	6.0
Elm	0.6	1.6	1.1	3.3	6.0
Cherry	0.5	0.6	0.1	1.2	2.2
Aspen	0.3	0.4	...	0.7	1.3
Basswood	0.3	1.0	0.5	1.8	3.3
Miscellaneous	0.7	1.0	1.5	3.2	5.8
Total	13.0	30.3	11.7	55.0	
Percentage	23.6	55.1	21.3		100.0

which means harvesting of the growing stock instead of the increment. Marketing will be an important factor only in the exceptionally good woodlands, whereas in the average farm woods it will serve as an outlet for excess material, mostly fuel wood, removed during improvements.

The distribution of the basal area on the 1058.3 acres as presented in Table II shows that the 32.1 per cent of the total number of trees within the 7–14-inch group represents 55.1 per cent of basal area found in the average woodland. It is noticeable also that the basal area is larger in the 2–6-inch group than in the group over 15 inches.

These findings indicate the need of intensive management and silvicultural practices to bring about the desirable restocking of the farm woodlands. The bulk of restocking in the merchantable class will originate, in the near future, from the present 7–14-inch class. The actual 2–6-inch class is potentially more important than the 7–14-inch class, because of the desirable combination of basal area and the distribution of tree species. From the data shown in Table II it is evident, however, that restocking and the distribution of age classes will approach normal conditions only after a considerable number of years.

DISTRIBUTION OF THE FARM WOODLANDS BY SLOPE AND SOILS

Most farm woodlands are on the "back forty" or in some inaccessible location of the operating unit rather than on land that is not suited to agriculture because of the soils and topography. As a means of evaluating the influence of soils and slopes on the quality of stands 20 woodlands comprising 353 acres were classified, regardless of soils and topography, on the basis of weighted averages, into three quality classes, namely, good, intermediate, and poor. The data obtained are shown in Table III.

TABLE III

STAND CONDITIONS ON TWENTY WOODLANDS

Class of woodland	Trees per acre	Basal area per acre in square feet	Merchantable volume per acre in cubic feet	Total volume per acre in cubic feet	Volume of board measure per acre. Trees over 10" d.b.h.	Annual increase	Increase: Per acre	Increase: Per year	Canopy
							Cubic feet	Board feet	
Good	197	78.3	1,231	1,597	6,527	3.4	49.4	195	0.8
Intermediate	119	62.5	926	1,108	4,576	3.2	37.5	142	0.7
Poor	113	52.3	679	883	3,798	2.8	24.5	105	0.6

The results in Table III were used as a yardstick, and 3,644 acres of woodlands distributed throughout the study area were classed as good, intermediate, and poor. The necessary soils and slope data were obtained from conservation survey maps.

The distribution of woodlands of various grades on the various slopes is shown in Table IV.

TABLE IV

QUALITY OF WOODLANDS ACCORDING TO SLOPES

Quality of woodland	Slope and area percentage					Total
	0–2	2–6	6–10	10–20	20 +	
Good	40.1	37.4	9.5	2.9	10.1	100.0
Intermediate	44.5	28.9	8.7	5.9	12.0	100.0
Poor	50.8	23.1	8.4	6.5	11.2	100.0
Weighted percentage of total farm woodlands on each slope	47.1	26.8	8.6	6.0	11.5	100.0

Table IV indicates that the frequency of good, intermediate, and poor woodlands is approximately the same on the various slopes; the slope, therefore, is not a significant factor with reference to potential quality of farm forests.

It was found that 71.5 per cent of good woodlands in the entire study area are on Miami and Hillsdale soils. These soils comprise 50 per cent of the wooded acreage, and only 7.9 per cent of the total woodlands are good. This indicates improper management, since the soils were capable of producing good woodlands. Other soils such as Fox, Bellefontaine, Oshtemo, Brookston, and Conover, along with Miami and Hillsdale, constitute approximately 80 per cent of the wooded area, but only 5.5 per cent of these woodlands are good. It is noticeable that none of the better woodland trees grow on the low, wet soils, such as Granby, Maumee, Carlisle muck, Edwards muck, Rifle peat, and Washtenaw. It is evident that regardless of slopes the Miami and Hillsdale soils rank highest as potential sources of timber production if the present lack in woodland management and silviculture can be corrected. Next in importance are the Fox, Bellefontaine, Oshtemo, Brookston, and Conover soils. On the wet soils intensive management and silvicultural practices are hardly justifiable under the present economic conditions.

MANAGEMENT AND SILVICULTURAL PROBLEMS

The easiest problem to solve is that of the protection of the woodland from fire and grazing. Most farmers realize that the pasturing of woodlands is a poor practice and are willing to fence out

livestock. Fire is not a serious problem in the woodlands of southeastern Michigan.

The present locations and conditions of the oak-hickory woodlands are the result of the lack of appreciation of land use and management dating back to the pioneer days. Proper land use should involve the gradual conversion of steep farm land to forests and the removal of woods from fertile, level, or slightly sloping land. Field study shows that a high percentage of the oak-hickory woodlands is on potential agricultural land. It also indicates that the better land produces the best trees. The existing woodlands, at least those on suitable locations and classed as good and intermediate, represent a capital growing stock that is valuable enough to be retained, and it should not be suddenly eliminated for the benefit of agricultural crops.

A question often raised is, What can be done to improve the oak-hickory farm woodland? In some instances protection answers the question, but we frequently find that protection alone will not suffice. Some thin and "sod-bound" woodlands may require interplanting to obtain a good stand of adapted trees in minimum time. In other woodlands, however, the natural reproduction obtained after protection has given far better results than the planting. It has been observed also that where mineral soil has been exposed by contour furrows adjacent to tree-planting areas, the natural reproduction is more satisfactory than on sites with unexposed mineral soil. This indicates that furrowing or disking in existing woodlands will have a positive influence on restocking.

Most of the cuttings needed consist of salvage and simple improvement of existing stands of timber. No harvest cuttings will be practicable for some time to come. The value of proper cutting has been proved on several check plots on and adjacent to improved areas under the same soil conditions. On the Kerber farm in Fenton Township the basal area increased by 1.7 per cent on an untreated area and 3.2 per cent on the treated one. Five standard cords of fuel wood out of a total of approximately 25 cords were removed from one acre during the improvement cutting. The growth of the remaining trees exceeded the total growth of the check plot by approximately 0.1 cord. On the Miller farm in Hartland Township the increase of basal area was 3.1 per cent on the untreated area and 3.3 per cent on the improved one. This woodland contains larger

trees and did not make so quick a response, but present indications point to growth as favorable as that in the Kerber woodland. Nine and three-tenths standard cords of wood and 700 board feet of saw logs were removed from one acre. This left approximately 17 standard cords and 2,400 board feet of saw logs per acre. There is every indication that proper management and cutting will be beneficial to most of the woodlands in the area.

CONCLUSION

1. The present woodlands of the oak-hickory type in southern Michigan are not properly stocked.

2. They contain a great deal of low-grade material and a relatively small number of merchantable trees.

3. Most of the soils studied will sustain, under management, economically justifiable woodlands, regardless of topography.

4. Woodlands have a definite place in the land use and economic patterns of farms.

5. Management and silvicultural field tests have positively demonstrated that oak-hickory farm woodlands will respond to suitable treatment.

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Soil Conservation Service
Howell, Michigan

A STUDY OF THE SPREAD OF FOREST COVER INTO WILD-LAND OPENINGS

NORMAN F. SMITH

THE rate of spread of forest cover into wild-land openings presents a problem of vital interest to public agencies dealing with game and forest management. There is definite need for a better knowledge of the return of forest vegetation into man-made openings so that we may know what to expect in the way of openings necessary to meet game requirements in 25, 50, or 100 years, and may have a guide to aid us in planning future planting programs.

Ecologically the study involves many factors, of which the three principal ones are the type of cover, the type of soil, and the type of opening, i.e. how and when it was formed. There must be considered, in addition, the competing vegetation, the availability of seed, the moisture requirements and tolerance of the tree species, the nature of the original forest cover, the age and composition of the surrounding forest, and the size of the opening.

A complete correlation and integration of all these factors would require a more intensive investigation than was undertaken by the writer. In this study an attempt was made to get only a general picture of the rates at which openings in various wild-land types have closed in the past, roughly, what percentage of them are still open and how fast they are closing. This paper will deal primarily with a discussion of the methods employed and will present very general results and conclusions.

METHODS OF STUDY

The first method of approach to the problem was the comparison of old photographs with recent ones. In the case of aërial photographs the interval of eight or nine years between the two sets available was too brief and the scale of the pictures too small for changes to be readily discernible; hence little positive information could be gained. The comparison of old ground pictures, made fifteen to twenty-five years ago, with those just taken from the

same locations proved to be very satisfactory and presented undeniable proof of changes that had or had not occurred over a period of years.

Another important part of the study was the examination of many individual openings in various types of cover and on various types of soil. Information on the history of these areas was obtained either from evidence on the ground or from local people. On the basis of the time elapsed since the opening had been created and its present condition so far as stocking was concerned, it was often possible to predict when the opening might be completely taken over by trees. Openings of many sizes were studied, ranging from an acre or less to more than a section and including burned-over land, cutover land, and abandoned farms. In this part of the work much valuable information was obtained on the effects of forest composition, ground-cover competition, soil, and past history on the rate of closing.

With these data as a background the next part of the study was undertaken, namely, to determine by a survey the extent of the openings on various soil types and in various cover types, and to show, so far as possible, how rapidly they were closing. For this purpose a strip-line transect type of survey was employed. Wildland areas were selected at random from soil maps in as many major soil types as possible. These areas were then traversed by car, and notes were taken on the cover composition, tree ages, history, and extent of the various cover densities observed. The smallest distance which could be recorded with any accuracy on the speedometer of the car was 0.05 of a mile or, roughly, 250 feet. Therefore any change of cover or density that did not approach 0.05 of a mile in extent was considered merely a part of the surrounding area, and was not treated as a separate piece.

Openings were classified according to tenths of density of cover. The densities started with 0, which applied to areas having no trees or established reproduction. The next gradation was 0+, in which there were widely scattered trees or trees moving in around the perimeter, but not enough to occupy one tenth of the available space. From there the densities increased in even tenths according to the estimated space occupied by the crowns.

The age of an opening was considered to be that of the oldest trees that had come into it since its creation. Age groups were set up to

cover ten-year intervals, with the exception of the first, which was 0 to 5 years. The rest ran 6 to 15 for the 10-year class, 16 to 25 for the 20-year class, and so on to the 60-year class.

Predictions of the length of time required for an area to close were divided into three groups: up to 25 years, 25 to 50 years, and over 50 years, with an extra group in which nothing could be forecast, marked simply X. These estimates were based on the time required to reach a 0.7 density, after taking into account the present density, the size of the area, the age classes represented, the reproduction present, and the availability of seed that will reproduce under existing conditions. A density of 0.7 for the purposes of this study was regarded as closed.

Areas to be cross-sectioned were selected from Land Economic Survey soil maps and from the land-type maps prepared by the Conservation Institute at Michigan State College. Wherever possible, straight roads were followed in order to get better cross sections. The strips were approximately four chains wide, two chains on each side of the road. Where the cover on the two sides of the road differed for any considerable distance information was recorded separately for each side. Conditions on both sides were usually the same, however, for most of the traveling was done on third-rate forest roads or worse.

RESULTS

In the manner described above 470 miles of strip line were covered in northern Michigan. Information was gathered on twelve major soil types, the total area of which represents over five million acres of northern Michigan land. Sixty-five per cent of the sampling was on the light sandy pine-oak soils, and 35 per cent on the loamy sands and sandy loams of the hardwood country.

In working up the data four general soil groups were made by combining soils of similar character. For the pine-oak type of cover these were the "pine-plains" group composed of Grayling and Rubicon sands, and the "oak-hills" group, which was Roselawn sand; for the hardwood type of cover the groups were the "loamy sands" and the "sandy loams." Densities were likewise grouped into "open," consisting of 0 and 0 + stocking; "poorly stocked," consisting of 0.1, 0.2, and 0.3 densities; "medium-stocked," consisting of 0.4, 0.5, and 0.6 densities; and "well stocked," 0.7 and over.

The data were compiled separately for each of the three types of openings — burned-over land, cutover land, and abandoned farms. A more detailed discussion will be given of the burned-over type than of the other two, about which only general statements will be made here.

Burned-over Land

Burned-over land comprised 80 per cent of the total area sampled, making up nearly nine tenths of the pine-oak land and two thirds of the hardwood land. By combining the data for all species and all soil groups many interesting trends can be shown. For example, 14 per cent of the land that burned at least 20 years ago is

TABLE I

PERCENTAGE OF TWENTY-YEAR-OLD ASPEN IN VARIOUS DENSITY CLASSES ON BURNED-OVER LAND

Density of stocking	Pine-oak cover		Hardwood cover	
	Pine-plains soils	Oak-hills soils	Loamy-sand soils	Sandy-loam soils
Well stocked......	3	32	9	36
Medium stocked ..	18	40	39	29
Poorly stocked	68	21	37	27
Open	11	7	15	8

still open, and an additional 36 per cent is poorly stocked, which makes a total of 50 per cent either open or poorly stocked after 20 years. After at least 30 years since the burning 11 per cent is in the open class and 26 per cent poorly stocked, making a total of 37 per cent in these two classes. This is a gain of 13 per cent in 10 years, or, in other words, 13 per cent moved out of these two low-density groups in the ten-year period.

On the other hand, 31 per cent of those areas burned at least 20 years ago and 34 per cent of those burned at least 30 years ago were in the well-stocked class, which indicates that only 3 per cent had moved into this well-stocked class in 10 years.

Comparisons of the rates of closing-in on various soil groups also show interesting results, many of them fairly well known in a general

way to observers of wild-land types. Let us take, for example, aspen (since it occurs on all four soil groups) in the twenty-year age class on burned-over land. Table I gives the present stocking of these lands on the various soil groups. It can be clearly seen from this table that the better forest soils have closed more completely in the twenty-year period.

Another example of comparisons that may be made is found in Table II, which compares the estimated rates of closing *in the future* for the same twenty-year age class of aspen on burned-over land. Figures here represent the percentages of twenty-year-old aspen type

TABLE II

Percentage of Twenty-year-old Aspen Stands on Burned-over Land Expected to Close within Various Periods

Rate of closing in years	Pine-oak cover		Hardwood cover	
	Pine-plains soils	Oak-hills soils	Loamy-sand soils	Sandy-loam soils
0–25	11	50	43	62
25–50	70	38	31	26
Over 50	17	3	24	12
X	2	9	2	0

in each closing group. This includes, of course, only those areas with densities of less than 0.7, those of 0.7 and over being considered already closed.

Here again the reactions on the better soils are clearly presented. The large percentage for the oak hills (Roselawn sand) type under "X" is due principally to the many pockets and depressions in these hills that apparently are kept open by frost.

Though the percentages in the two tables are not to be accepted as absolutely accurate, they nevertheless serve to indicate very definite trends.

Information of the same type as that presented in the tables can be set forth for the other principal cover types and age classes. A comparison on the same basis of all age classes and cover types combined reveals the same general trends as for the twenty-year aspen stand.

Nearly three fourths of the burned-over areas sampled were in the 20-, 30-, and 40-year age classes, hence more reliance can be placed on the data in these classes than in those above and below.

Most of the burned-over areas that are well stocked and many that are medium-stocked are essentially even-aged, the result of the initial spurt of sprouting or seeding immediately after the fires. Many of the poorer soils probably lacked the capacity to support most of the seedling reproduction after it germinated; hence these areas contain only scattered trees; and without fires to stimulate sprouting of certain species, or to create better seedbed conditions, they must close up by the long, slow process of normal root sprouting. Measurements made on several clumps of aspen spreading by root suckering show that the rate of spread is approximately two feet per year in one direction. Similar measurements for pin cherry reveal that its rate is approximately two and one-half to three feet per year. The soil type made no appreciable difference. At this rate there are many areas of not over forty acres that would require over two hundred years to fill in were the spread to be by sprouting alone. What other factors might interfere cannot be predicted.

Unburned Cutover Lands

Cutover lands that have not burned since logging comprised approximately 15 per cent of the total area sampled, representing 3 per cent of the pine-oak type and 26 per cent of the hardwood type. Most of the cutover lands in the pine-oak cover type were jack-pine areas on the pine-plains soils. In general, under the clear-cutting practice usually followed on privately owned land of this type the areas are slow to come back, but all appear to be making some headway. Jack pine, cherry, and oak are the principal species coming in. Sod competition is apparently responsible for most of the delay.

So little cutover land on the oak-hills soil type was sampled that no reliable comparisons of closing-in rates can be made. It may be said, however, that the rates would depend largely on the amounts of oak and aspen that were cut and thus would sprout, the availability of red-pine and jack-pine seed, and the nature and completeness of the ground cover.

Little need be said about the closing-in of hardwood areas after cutting, since in nearly all of them hardwoods rapidly reoccupy the sites by sprouting from vigorous stumps or by the growth of ad-

vanced reproduction present before the cutting. Two thirds of the areas clear-cut ten years ago were in at least the 0.5 density class and were closing rapidly. Over 90 per cent had reached at least a 0.7 density twenty years after cutting. It appears that those hardwood areas that were not well closed up within twenty years after cutting had originally very little advanced reproduction and were composed principally of large mature trees, the stumps of which rarely sprout. Little difference was noted between the rates of closing on the loamy sands and on the sandy loams in the hardwood cutovers.

Abandoned Farm Land

Approximately 5 per cent of the total area covered was classed as abandoned farm land. This type of land was frequently difficult to determine, particularly on jack-pine plains, and possibly some of the land which was included as "burned-over" may have been farmed or pastured. Much of it, covered with grasses and having perhaps a few scattered trees, was burned over after abandonment, and filled in quite rapidly and completely with jack pine or aspen. Certain abandoned farm areas in hardwood country at present containing heavy sod and scattered elm trees may possibly have been pastured after the timber was cut. Since cattle do not like the rough leaves of the elm, this species was left to grow unmolested while maple and many other species were browsed out. An area was classed as burned-over, however, unless it could be definitely established as old farm land.

In the pine-oak areas 44 per cent of the abandoned farm land was closing so slowly that no attempt could be made to predict when it might be closed. Jack pine, red pine, cherry, and aspen were doing most of the pioneering, and there was little difference between the rates of closing on the two soil groups of this type.

In the hardwood areas 80 per cent of the farm land sampled was in the unpredictable class. Heavy sod, grasshoppers, scarcity of pioneer species in the surrounding cover, all contribute to make the process of closing extremely slow. There appears to be little difference between the rates of closing on loamy sands and sandy loams since heavy sod, which hinders seed germination, rapidly takes over the areas on each type, and the pioneer species spreading by root suckers make the same slow progress. It appeared that many of these areas would remain open indefinitely.

SUMMARY AND CONCLUSIONS

Though many areas and soils have not been included in this report, nevertheless those in northern Michigan about which there is most speculation have been, at least in some degree. One particular group of soils, which did not fit into either the dry pine or the hardwood soils, but which represents a considerable area, is the wet sandy-plains group, composed principally of Saugatuck sand and Newton loamy sand. In general, the cover on these soils has closed up rapidly since the areas were burned; the present cover is chiefly aspen and willow, with cherry and white birch in spots. Many small islands of drier ground are still open and are closing very slowly. They usually have a over of heavy sod, which hinders seeding.

In connection with the upland soil types, which were the principal subject of this problem, it can be said in general that the period of rapid natural closing-in of the old burned-over areas not already partly stocked is past. It is reasonable to assume that areas of any size that have lain virtually open for the past twenty or thirty years are not going to close in another twenty or thirty years. It is true that, as time goes on, more seed will be available from maturing trees on and surrounding the openings, but, barring fires, the ground cover is not going to be any more receptive to seed germination. The restocking of large areas by a normal process of root sprouting is extremely slow and uncertain. Where there is at present a scattered stocking of trees representing many age classes, including young seedlings, it is reasonably certain that the process of seeding will continue, and the area will eventually close in. Where the area has widely scattered trees all of one age, a condition found in many oak-sprout stands, it is difficult or impossible to make any prediction.

With only a little more than 25 per cent of the sampled area at least 0.7 stocked, 75 per cent is in various stages of closing or is entirely open. In the medium-stocked group, representing 25 per cent of the total area sampled, 75 per cent will apparently close within 25 years, and 20 per cent in between 25 and 50 years. The remaining 5 per cent will require over 50 years.

Of the areas poorly stocked at present, representing 33 per cent of the sample, approximately 20 per cent will close in 25 years or less, 50 per cent in 25 to 50 years, and 25 per cent in over 50 years. The remaining 5 per cent will possibly remain as it is indefinitely.

Of the areas that are now essentially open, i.e. less than 0.1 density, representing 15 per cent of the total of all classes of openings, cover types, and soils sampled, present indications are that nearly 50 per cent will require over 50 years to close, and 40 per cent will remain open indefinitely.

By combining the open and poorly stocked groups, which represent approximately 50 per cent of the area sampled and which are the areas of most interest, it is found that 15 per cent will close within 25 years, that 40 per cent will close in 25 to 50 years, and that 45 per cent will require well over 50 years or will remain open indefinitely.

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ZOOLOGY

ANNULUS FORMATION ON THE SCALES OF CERTAIN MICHIGAN GAME FISHES *

WILLIAM C. BECKMAN

THIS investigation on the annulus formation on the scales of Michigan game fishes was begun in September, 1938, when the writer undertook the growth-rate studies for the Institute for Fisheries Research of the Michigan Department of Conservation. It soon became apparent that one of the first problems was to delimit the time or period of year at which the annulus or year mark forms on the scales of certain of the game fishes of Michigan. The precise determination of the age of fish collected in spring and early summer was difficult, and at times impossible, because of the lack of exact information on the time of annulus formation. On many scales it was hard to decide whether the marginal area outside the last annulus represented the new season's increment or the entire last year's growth. If the year mark of the previous winter had already formed, the age as determined by the number of completed annuli would be correct, but if the mark had not been completed, the fish would be one year older than the age indicated by the number of annuli.

In order to solve this main problem conclusively it was necessary to demonstrate that the annulus on the scale of the fishes studied corresponds structurally with the year marks which have been found in various species by other workers, and to secure evidence that the annulus is formed each year and only once annually.

It was apparent, also, that the solution of the problem of the time of annulus formation would contribute in other ways to an understanding of fish growth. For instance, evidence would be secured on the factors responsible for the formation of the annular rings. The periodic sampling would make it possible to determine at which part of the growing season the growth is fastest. It would be possible, also, to trace the course of growth during one season. Furthermore,

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

an analysis could be made of possible differences in the growth of the sexes, and of various age groups and sizes of fish. Although data were obtained on all these problems, this report is concerned primarily with the time and cause of annulus formation.

The writer is indebted to the Michigan Department of Conservation, whose Institute for Fisheries Research furnished all equipment and expenses for the study as well as financial aid in the form of an assistantship on its staff. Acknowledgment is made of the assistance and direction given during the investigation by Dr. A. S. Hazzard, director of the Institute. The writer also wishes to thank the various members of the Institute staff, other employees of the Fish Division of the Michigan Department of Conservation, and all others who helped further the investigation. For guidance and valuable advice throughout the course of graduate study and in carrying out this investigation he wishes to thank Dr. Carl L. Hubbs, of the University of Michigan. Thanks are also due to Dr. Ralph Hile, of the United States Fish and Wildlife Service, for his assistance and advice.

SOURCE OF MATERIALS

For the monthly collection of scale samples which comprise the material used in this investigation eight waters (seven lakes and a pond; Fig. 1) were selected at the beginning of the work. These waters were chosen so as to insure a range of samples for several species from south to north. Collections were made of the species listed at the following places on the dates given:

Clear Lake, Jackson County (area, 137 acres; maximum depth, 35 feet):[1] January, February, April, June, July, and December, 1939, and May and June, 1940. Game species: yellow perch (*Perca flavescens*), largemouth bass (*Huro salmoides*), bluegill (*Lepomis m. macrochirus*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites r. rupestris*), and black crappie (*Pomoxis nigro-maculatus*).

Pasinski Pond, Livingston County (area, 4½ acres; maximum depth, 5 feet): September, 1938, April, May, June, July, and September, 1939, and February, 1940. Game species: bluegill.

Budd Lake, Clare County (area, 175 acres; maximum depth, 34 feet): May, June, and October, 1939, and May and June, 1940. Game species: yellow perch, largemouth bass, bluegill, pumpkinseed, rock bass, and black crappie.

Round Lake, Emmet County (area, 336 acres; maximum depth, 27 feet): May, June, and October, 1939, and May and June, 1940. Game species: perch, largemouth bass, bluegill, pumpkinseed, and rock bass.

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[1] The descriptive statements regarding each lake are taken from the maps and survey records of the Institute for Fisheries Research.

FIG. 1. Location of the lakes from which the major collections were made and limits of the three temperature zones into which the state was divided

North Manistique Lake, Luce County (area, 1,722 acres; maximum depth, 50 feet): June, July, September, and October, 1939, and May, June, and July, 1940. Game species: yellow perch, walleye (*Stizostedion v. vitreum*), smallmouth bass (*Micropterus d. dolomieu*), and rock bass.

Bass Lake, Marquette County (area, 400 acres; maximum depth, 30 feet): June, July, September, and October, 1939, and May, June, and July, 1940.

Game species: yellow perch, walleye, smallmouth and largemouth bass, bluegill, and pumpkinseed.

Crooked Lake, Gogebic County (area, 566 acres; maximum depth, 66 feet): July, August, September, and October, 1939, and May, June, and July, 1940. Game species: yellow perch, smallmouth and largemouth bass, bluegill, pumpkinseed, and black crappie.

Lake Fannie Hooe, Keweenaw County (area, 231 acres; maximum depth, 48 feet): July, August, September, and October, 1939, and May, June, and July, 1940. Game species: yellow perch, smallmouth bass, bluegill, and rock bass.

In connection with other investigations for the Institute for Fisheries Research some data were taken on three additional lakes:

Standard Lake, Cheboygan, Charlevoix, and Otsego counties (area, 32 acres; maximum depth, 31 feet): May, June, and October, 1939, and May, 1940. Game species: yellow perch, smallmouth bass, and rock bass.

Ford Lake, Otsego County (area, 12 acres; maximum depth, 39 feet): May, 1939, and May, 1940. Game species: bluegill.

Deep Lake, Oakland County (area, 15 acres; maximum depth, 61 feet): February, April, May, June, July, and August, 1939, April, May, June, July, August, and September, 1940, and April, May, June, July, August, and September, 1941. Game species: largemouth bass, bluegill, pumpkinseed, and rock bass.

COLLECTION, PREPARATION, AND EXAMINATION OF SCALE MATERIAL

The collections were made with three to nine gill nets (5 by 125 feet, of five mesh sizes, grading from 1½ to 4 inches, stretched measure), with seines, and with a river fyke net (9 feet long, with 5-foot wings and made with 2-inch stretched-measure mesh). Rod-and-line fishing also was employed in the taking of samples.

Length, weight, sex, and state of sexual maturity were recorded, and scale samples were taken. Both standard length, the length of the fish from the tip of the snout to the end of the vertebral column, and total length, the greatest measurable length of the fish, were recorded to the nearest millimeter. All weights were recorded to the nearest gram, with the exception of those of a few large fish (walleyes), which were weighed to the nearest half ounce.

In the laboratory the scales were prepared in the customary manner and mounted on glass slides in a glycerin-jelly medium. They were examined on a projection machine similar to the one described by Van Oosten, Deason, and Jobes (1934). Measurements were made along the most nearly vertical anterior interradial space. The positions of the annuli were marked on 1- by 11-inch tagboard strips.

Measurements in millimeters for computations were taken from these strips.

The data were tabulated on "growth-analysis cards" used by the Institute for Fisheries Research, according to species, date of collection, sex and age group, and under age group by size.

THE SCALE METHOD

This investigation is designed to render more precise the determination of the age of fishes by the scale method. The age of the fish is determined by counting the number of annuli or year marks on the scale. The general validity of this method has been assumed. That the annuli on the scales do provide a clue to the fish's age and growth has been demonstrated for many species and is now confirmed for the material used in the present study.

The structure of the scale and the character of the annulus are described below. All the fishes used in the present study have ctenoid scales, which may be exemplified by a photograph (Pl. I, Fig. 1) of a scale from a bluegill, 4¼ inches long, caught on June 14, 1939, in Pasinski Pond, Livingston County. In the center of the scale is a very small clear area, the focus, which represents the original scale of the young fish. Around this center are numerous ridges or circuli, which represent successive stages in scale growth, though they seldom correspond exactly with the scale margin. The posterior or free part of the scale bears the ctenii. On the anterior, concealed, field are the radiating grooves, known as radii.

As the scale grows, each circulus is laid down first along the anterior margin and gradually grows around the scale. A close examination usually will show several incomplete circuli along the dorsal and ventral borders of the scale (left and right in the figure). During the winter, growth is retarded or ceases entirely, and the circuli do not grow to completion. With the resumption of rapid growth in the spring a new circulus is laid down which soon grows around the entire scale margin, just outside the incomplete circuli of the previous growing season, which remain as they were in the winter. The new circulus therefore cuts across these incomplete circuli, and this "cutting over" is one of the most conspicuous and trustworthy characteristics of the annulus or year mark.

The cycloid type of scale lacks ctenii. The circuli usually extend around the entire scale, although they may be weak or absent on the

posterior portion. The annulus is formed in the same general manner as on the ctenoid scales, and is recognized by the same criteria. On examination of the scale (Pl. I, Fig. 2) from an 11-inch cisco (*Leucichthys artedi*), caught on December 1, 1934, in Blind Lake, Washtenaw County, it will be seen that there is an alternation of light and dark bands, made up respectively of widely and narrowly spaced circuli. These bands are usually more pronounced on the cycloid scales, although some ctenoid scales exhibit them also, and some scales of either type do not show them.

Early workers treated these distinct zones as summer and winter bands, but failed to define the incomplete circuli as the chief diagnostic character of the annulus. Hoffbauer (1898, 1900), however, had described the true character of the annulus, and had offered proof of its validity as a year mark. Other works of his (1901, 1904, 1905, 1906) provided confirmatory evidence. Masterman (1913) also pointed out the true nature of the annulus on the salmon scale, as Hoffbauer had done for the carp. Nevertheless, many workers (Gilbert, 1922; Snyder, 1923; and others) continued to interpret the "winter band" as the year mark.

The annuli formed on the scales of the game fishes of Michigan that were studied are of the same character as those described by the majority of workers.

Reviews of the literature and bibliographies on the scale method have been given by Thomson (1904), Taylor (1916), Hutton (1921), Creaser (1926), Mohr (1927, 1930, 1934), Graham (1929), and Van Oosten (1929).

The assumption that the annulus is a year mark and that but one annulus forms each year has been and still is under criticism. This question has been studied in a number of experiments. Hoffbauer (1898 to 1906), in presenting the major foundation of the method, followed the growth of carp of known age in a pond for three years, and made observations concerning the scale characteristics of several other species (*Carassius carassius, Lucioperca sandra, Abramis brama, Esox lucius, Leuciscus erythrophthalmus, and Leuciscus cephalus*). By laboratory or pond experiments Dahl (1911), Mohr (1916), Van Oosten (1923), Creaser (1926), and others furnished basic information on annulus formation. Johnston (1905, 1907) and many later workers, for example, Hutton (1909, 1910), Gilbert (1913), and Fraser (1921), tested the theory by tagging experiments.

Lea (1910), Hjort (1914), and others, in following the dominant year class through commercial catches for several years, determined that one additional annulus appeared on the scales of members of this year class each year. Lea (1911), Fraser (1916, 1917), and others traced the marginal scale growth throughout the year by periodic sampling, and thus obtained evidence to show that only one annulus a year was formed by the species studied.

Contrary evidence also has been gathered which tends to indicate that the determination of the true annuli may not always be a simple matter. Other marks have been described on scales, which, though not true annuli, are often mistaken for them. Jacot (1920) believed that the annulus of the mullet was a migration check. Spawning marks have been described on many scales (Johnston, 1905; Calderwood, 1911, 1914; Hubbs and Cooper, 1935). Hubbs (1921) also described a "metamorphic annulus" on the scales of viviparous perches (Embiotocidae), brought about by a temporary retardation of growth at birth, in the summer. Bennett, Thompson, and Parr (1940) observed that several annuli may form in one season on the scales of a certain percentage of bluegills and largemouth bass in Illinois. Further discussion of this subject will be made in later sections.

FACTORS OF ANNULUS FORMATION

The formation of the annulus is obviously dependent upon the retardation or cessation of growth, followed by a resumption of growth. As Van Oosten (1923) pointed out, growth of the body and scale is closely correlated, and any factor affecting the growth rate of the body may be of primary significance in the formation of the annulus. The problem, then, is largely one of determining the factors that are responsible for the seasonal growth rhythm of the fish.

Temperature

Many authors have held that temperature is the most important factor in the formation of the annulus. The views of Fulton (1904) are as follows: "Temperature is active in modifying the rate of growth by acting directly upon the metabolism of the fish and also by affecting the rapidity of digestion. In very cold water the fishes give up feeding altogether, because the ferments upon which digestion depends do not act, or act very slowly, at low temperatures, and

in fishes, as in other animals, appetite waits on digestion, and this is, on the other hand, correlated with the metabolism in the tissues. It has been shown by Krukenberg that the pepsine or analogous body in the stomach of fish acts as well at 20° C. as at 40° C., at which, among mammals, digestion is most active, and that the rapidity of its action is closely related to the temperature, and Knauthe and Zuntz have shown that the same thing applies to the metabolism in fish, the vital activities being more active in the higher temperature, as shown by the excretion of carbonic acid gas and other products of metabolism."

Thomson (1904) held that "the divergence in growth of the scales during summer and winter is probably due to changes in the general metabolism of the body, which are in their turn, in all probability, the result of seasonal variation in temperature and food supply."

In 1911 Lea stated that there was no close dependence between temperature and growth rate, but that the rate of growth rises as soon as the temperature begins to rise in the spring.

Cutler (1918) wrote in regard to temperature: "The conclusions which I draw from the results of these experiments on the scale growth of fish is, that the broad summer bands, which are caused by the sclerites during the period being wide, and the narrow winter bands, produced by narrow sclerites, are due to changes in the temperature of the water in which the animals live. High temperatures, such as are found in summer months, lead to formation of broad sclerites, while narrow ones are called forth by low winter temperatures."

Van Oosten (1923) stated that "temperature appears to be a primary factor in the formation of annuli in the adults, but only a secondary one in the immature fish."

To determine at just what temperature the annulus forms in southern Michigan a thermograph was set up at Deep Lake, Oakland County, on April 22, 1940. It was removed in September and reinstalled on April 18, 1941. The temperature records for the period during which the annulus formed are summarized in Table I.

The data obtained by means of the thermograph indicate that annuli are formed in the spring at a fairly definite temperature. In both 1940 and 1941 no annuli were observed before the mean daily water temperature exceeded 50° F. The mean temperatures of the days on which the collections first showed annulus formation were 53° F. (May 10) in 1940 and 52° F. (April 22) in 1941. The mean

TABLE I

TEMPERATURE RECORD FOR DEEP LAKE DURING PERIOD OF ANNULUS FORMATION

The thermocouple was located on a shaded area of sandy shoal, on bottom at depth of 18 inches. The dates of annulus formation were May 8–20 in 1940 and April 22–May 5 in 1941.

Week	Temperature, degrees Fahrenheit (Centigrade in parentheses)		
	Mean minimum	Mean	Mean maximum
April 28–May 4, 1940	42 (5.6)	45 (7.2)	49 (9.4)
May 5–11, 1940	49 (9.4)	52 (11.1)	56 (13.3)
May 12–18, 1940	52 (11.1)	55 (12.8)	59 (15.0)
May 19–25, 1940	53 (11.7)	57 (13.9)	60 (15.6)
April 21–27, 1941	48 (8.9)	51 (10.5)	54 (12.2)
April 28–May 4, 1941	56 (13.3)	60 (15.6)	64 (17.8)
May 5–11, 1941	55 (12.8)	59 (15.0)	62 (16.7)
May 12–18, 1941	55 (12.8)	59 (15.0)	62 (16.7)

temperatures of the first days on which a majority of the fish in the collections had formed annuli were 58° F. in both 1940 (May 13) and 1941 (April 28). It should be noticed particularly that the annuli were completed approximately two weeks earlier in 1941 than in 1940, but that the temperatures at the time of annulus formation were almost exactly the same in the two years.

Markus (1932) determined that largemouth bass did not feed readily at 10° C. (50° F.) and that at 4° C. (39° F.) none took food voluntarily. From his experiments Hathaway (1927) reached the following conclusions in regard to bluegill, pumpkinseed, and largemouth bass: "When fishes were tested at 20° [68° F.] and then transferred to 10° the food consumption the first week at 10° was, on the average, about one-third of what it had been at the higher temperature. . . . During the second, third, and fourth weeks at 10° there was, in several cases, a further decline, the average food eaten per day for the fourth week amounting to 27 per cent of what it had been at 20°."

A rough correlation was found between mean monthly air temperatures (drawn from records of the United States Weather Bureau) and the time of annulus formation. This point will be discussed in the section on "Time of Annulus Formation."

Temperatures higher than the optimum for the species also tend to retard or stop growth. Audigè (1921) ascertained that certain temperate-zone fishes (*Cyprinus carpio, Carassius auratus,* and *Scardinius erythrophthalmus*) grew irregularly, with frequent checks, when held in water at 24–25° C. (75–77° F.) and that these checks were more pronounced at temperatures between 30° (86° F.) and 31° C. (87.8°F.). Similarly, it is known that the scales of tropical marine fishes often show annulus-like marks far too numerous to represent years. It is possible that the several annulus-like marks which formed in one year on the scales of some of the bluegills and largemouth bass in Fork Lake, Illinois (Bennett, Thompson, and Parr, 1940), were induced by the high summer temperatures, which led to a temporary cessation in growth. The weekly average water temperatures listed by these authors for the depth of three feet reached 85° F. (29° C.) for one week and remained over 75° F. (24° C.) for sixteen weeks from May 22 to September 18, 1939, with the exception of one week beginning June 12, when the mean temperature was 74° F. (23° C.). A collection made the following week (beginning June 19) exhibited the first accessory mark. Thus age determinations may be unreliable in shallow lakes where very high water temperatures occur over considerable periods.

Spawning

Spawning appears to have little effect on the time of annulus formation. The yellow perch spawn in early spring, but they form their annuli at about the same time as the late spawners. Johnston (1905, 1907), Taylor (1916), Morosov (1924), Hubbs and Cooper (1935), and others record that spawning marks, distinct from true annuli, are formed on scales. Many of the scales examined in this study exhibited accessory checks, which may be interpreted as spawning marks. These structures are most distinct on the anterior field. Further investigation is being carried on in an effort to determine the exact nature of these marks.

Food

Food has been considered of chief importance as a factor in annulus formation by Hoffbauer (1898, 1900), Thomson (1904), Fraser (1917), and Bhatia (1931). Van Oosten (1923), however, stated that

food is only a secondary factor in adults, but may be a primary factor in immature fish.

The author does not believe that food is often the primary factor. It has been shown by several workers (see discussion under "Temperature") that fish eat very little or no food at low temperatures, even when the supply is abundant. It would seem that temperature is more important than food as a factor directly controlling growth.

To be sure, if food is lacking, high temperatures would hardly be expected to induce the resumption of growth, which is essential in annulus formation. According to Hansen (1937), under certain conditions of malnutrition the white crappie (*Pomoxis annularis*), in Illinois, forms an absorption annulus that resembles the spawning mark which develops on the scales of salmon when they are spawning but not feeding. If the absorption of the scale can be taken as an indication of starvation, as Hansen suggested, the late formation of the annulus, found in these fish by Hansen, may well be attributed to a lack of food and a consequently long delay in the resumption of growth. This situation, however, is probably exceptional. The writer did not find any annuli of this absorption type on any of the thousands of scale samples of Michigan fishes.

It is possible also that the metamorphic or "natal" annulus of the Embiotocidae (Hubbs, 1921) is formed on a nutritional basis, for at birth the embryonic food supply is cut off, and retardation or even a temporary stoppage of growth may ensue before the young fish become adapted to the capture of the new type of food.

As Creaser (1926) emphasized, cessation and resumption of growth are the immediate factors involved in the formation of the annulus. Obviously, food can be a primary factor in annulus formation under those conditions in which these changes in growth are primarily determined by the supply of food organisms available.

TIME OF ANNULUS FORMATION

Few references to the time of annulus formation were made by the earlier workers on the age and growth of fishes. For the most part they were content to call the annulus the "winter mark" and apparently gave little consideration to the time of year at which the mark formed. A few men, however, directly or indirectly contributed data on this point.

Johnston (1905) found that the growth had begun at the end of

April on the scales of the salmon (*Salmo salar*) from the River Tay.

For the eel Gemzöe (1908) stated: "The growth of the scales begins in June, or, as a rule, first in July, and is ended at the end of September — sometimes (as in the silver eel) the growth ends somewhat earlier, seldom later."

The year mark was on the edge of the scales of the salmon taken in Ireland during January, February, and March, after which it was found within the edge in an increasing percentage. In May, June, and July collections from Norway the scales had the mark inside the edge in an increasing percentage, although some individual variation occurred (Dahl, 1911).

Lea (1911) showed that many of the herring scales collected on April 5–7 from waters near Bergen, Norway, had a small amount of new growth, whereas others taken at the same time did not. The fish of a sample taken on April 23 had formed new growth on the scales. Concerning Canadian collections, Lea subsequently stated (1919): "These later samples give a more definite idea as to the time when summer growth of the younger herring in these waters [off Prince Edward Island] begins, as in one of the samples (early June) the fish had not commenced their growth, while the remaining samples revealed a distinct new summer belt on the scales.

"An interesting feature in connection with these fish is the fact that summer growth commences so late. Off the coast of Norway, the new summer growth commences in April; but far up in the Baltic, near the coast of Finland, similar conditions are observed. Hellevaara . . ., who has investigated the herring of these waters, observes in this connection: 'Not until the 27th of June did I observe that the scales had begun to grow on the young fish 1 or 2 years old; but not on those which had reached maturity.'"

Sund (1911) found the location of the winter ring to be at the edge of the scales of the sprat (*Clupea sprattus*) taken in April, a short distance inside the margin in those collected in May, and again on the margin in a December sample. (It is doubtful, however, if the new annulus had formed in December).

In River Wye salmon Masterman (1913) discovered a marginal growth band of increasing width from April to September, but not in those taken in November and December.

The year mark is formed on the scales of the squeteague

(*Cynoscion regalis*) and pigfish (*Orthopristis chrysopterus*) in May or June (Taylor, 1916).

Fraser (1917) thus sums up his investigation: "In all scales of salmon [*Oncorhynchus tschawytscha*] caught from January 6 to March 17, there was indication of the check in growth at the margin. On the other hand, with but few exceptions, no scales obtained after April 22, and before November 27, had indication of retardation at the margin. From March 17 to April 22, and from November 27 to January 5, some show retardation at the margin while others do not, this being true even in specimens caught the same day." The author obviously did not distinguish the "dark band" of narrowed circuli from the true annulus. For the chinook salmon of the Columbia and Sacramento rivers Rich (1920) stated that growth is practically negligible from November to March, but more rapid growth is apparently resumed in April and May.

For the herring from the English Channel Hodgson (1925) showed that: "(1). The scales of English herring begin to grow during April and cease to grow in September, irrespective of their geographic position; (2). Younger fish have a longer growing period than older ones; (3). The older fish have a tendency to begin growth later than the younger fish." In Norwegian waters the scales of the herring had begun their growth in May (Lissner, 1925). In the haddock of Scottish waters Thompson (1926) found that the year mark always formed in March.

In 1941 Merriman stated: "Actually for the striped bass, the annulus does not appear in winter, and only becomes evident by April or May."

The papers mentioned above deal chiefly with ocean or river-run fish. Literature dealing with the time of annulus formation in fresh-water fishes is also scanty. The following workers, however, have presented some data on the subject.

Van Oosten (1923) states that for the whitefish "the marginal growth is resumed sometime in April (or March?)." Creaser (1926) observed that "At Douglas Lake, Michigan, an investigation of the scales of many of the fishes showed that in June an annulus had only recently been formed."

For the bully (*Gobiomorphus gobiodes*) in the Lower Selwyn River, South Island, New Zealand, Parrott (1934a) wrote: "It should be noticed that the summer annuli [wide circuli] are principally formed

during October, November, and December, while the winter annuli [narrow circuli] are formed principally during March, April, and May. There is, generally speaking, no growth in the scale during June, July, August, and September." He stated, further (1934b), that in the brown trout (*Salmo trutta*) the summer bands begins to develop in September and that by the end of October the majority show summer growth.

On the contrary, Hansen (1937) found that the annuli are formed over a long period in certain waters of Illinois. "In 1935 it was May, June, and July; in 1936, May, June, and possibly July."

According to Eschmeyer (1939), "Annulus formation in some of these immature fish [largemouth bass of Norris Reservoir, Tennessee] therefore extended over a long period, for a few had formed an annulus early in May and others had not begun growth by June 1, assuming that initial growth is reflected on the scale. . . . Two walleyes, taken late in March, had formed no annulus; 21 taken in late May and early June had made some growth; one caught in late May had not yet formed an annulus." In further studies on fish of the Norris Reservoir Jones (1941) determined that the growing season for the smallmouth and largemouth bass begins in June and ends early in October or late in September.

In a study mentioned on page 290 Bennett, Thompson, and Parr (1940) recorded the following observations: "Some of the yearling bluegills had formed annuli on their scales before April 18, and all of them had formed annuli by the end of May. Most breeder bluegills began annulus formation later than the yearlings, and did not complete this formation until October. Annulus formation in the bass extended from mid-April to late September."

For the white perch (*Morone americana*) Cooper (1941) stated that the growing season in Maine in 1940 extended from about the first or the second week in July through August and possibly through part of September.

Hile (1941) discarded a collection of old rock bass captured in Nebish Lake, Wisconsin, on July 5 and 6, 1930, because of his inability to decide whether certain individuals had formed the 1930 annulus. Annulus formation had been completed in the younger rock bass of a collection made July 1 and 2, 1932, in the neighboring Muskellunge Lake, but individuals of the same collection older than six years rarely exhibited a completed year mark.

The time of year at which the annulus forms in Michigan is distinctly earlier in the southern than in the northern part of the state. The extent of the difference is shown in Table II, where it may be seen that the year mark was formed and some marginal growth was evident on the scales of the fishes taken in the southern one third of the Lower Peninsula on May 17–20, 1940, whereas the scales of fish collected in the Upper Peninsula on May 22 had not yet begun to grow.

The statements of the following paragraphs in regard to the time of annulus formation in the different lakes apply to all species in each lake. (For details concerning species and the numbers in the collections see Appendix.) The lakes will be considered in the order in which they appear in Table II, with the exception of Pasinski Pond. The materials from this pond are of such a nature as to require a special discussion.

On some of the scales obtained from Clear Lake (Zone 1) on April 28, 1939, there was an annulus on the edge, and others had a trace of this mark. All those secured on June 1, 1939, when the lake was next fished, exhibited a completed annulus and a margin of new growth. The marginal annulus had formed on some of the scales taken on May 7, 1940, whereas on others there was only a trace or no indication at all of the year mark. The scales next collected here, on June 6, all showed an annulus well inside a margin of growth.

Data pertinent to the problem of the time of formation of the year mark were collected in Deep Lake (Zone 1) in connection with other investigations during 1939, and a special effort was made in 1940 and 1941 to take scale samples at frequent intervals. Certain aspects of these data have been discussed earlier (p. 291), in connection with the study of the factors of annulus formation.

None of the scales had a completed annulus in the first spring collection of April 27, 1939, although a few showed the beginning of one. There was no annulus on the scales taken on April 29. The next collection was made on May 17, at which time an annulus and a narrow band of growth were found on each scale.

In 1940 collections were begun on April 24. Samples taken then and on April 25, 29, 30, May 2, and May 8 had no annulus. On May 10 a few of the scales exhibited an annulus. On May 13–14 all but six of the samples had the year mark at the margin. Collections of May 20–22 showed the annulus within a narrow but distinct margin of growth.

TABLE II

TIME OF ANNULUS FORMATION ON THE SCALES OF GAME FISHES IN MICHIGAN

(See Appendix for details concerning the collections on which this table was based.)

Year	Zone	Lake	Dates when no scales had formed a marginal annulus		Dates when some scales had formed a marginal annulus			Dates when all scales had formed a marginal annulus	
			Date	Number of specimens	Date	Number of specimens		Date	Number of specimens
						with	without		
1939	1	Clear	Jan. 19 Feb. 25, 28	2 15	April 28 ...	7 ...	6 ...	June 1 July 15 Dec. 31	59 32 14
		Pasinski Pond	April 18 April 23	46 152	... ...	... ...	... ...	April 29 May 28 June 14–Oct. 12	38 69 327
		Deep	Feb. 2 April 27 April 29	2 8 5	... ...	... ...	... ...	May 17 May 19–31 June 2–Aug. 4	38 56 169
	2	Budd	...	...	May 17	59	14	June 19 Oct. 28	175 17
		Round	...	...	...	...	...	May 25 June 24 Oct. 20	15 77 7
	3	North Manistique	...	...	...	...	...	June 26 July 28 Sept. 7 Oct. 21	76 111 21 15

		Bass	...	...	...	...	...	June 25 July 4 July 29 Sept. 15 Oct. 22	16 26 72 6 16
		Crooked	...	...	...	...	...	July 1–3 July 31 Aug. 26 Oct. 23	68 38 70 14
		Fannie Hooe .	...	...	...	...	...	July 4–6 Aug. 2–4 Aug. 30 Oct. 24	31 48 11 3
1940	1	Clear	...	...	May 7	13	31	June 6	53
		Deep	April 24, 25, 29, 30, May 2, 8	84	May 10 May 13 May 14	5 37 21	34 3 3	May 20 May 22, 27, June 14	11 68
	2	Budd	...	...	May 17	20	80	June 19	57
		Round	May 20	13	...	...	...	June 21, 22	50
	3	North Manistique.......	May 22, 23	53	...	...	...	June 24 July 20, 21	28 49
		Bass	May 24	36	...	...	...	June 25 July 23–24	29 59
		Crooked	May 26	30	...	...	...	June 26 July 27	17 49
		Fannie Hooe .	May 27–28	12	...	...	...	June 27 July 27–29	18 39
1941	1	Deep	...	...	April 22 April 24 April 26 April 28 May 1 May 3	1 12 13 25 20 24	18 39 25 9 3 1	May 5 May 7, 9, 12, 16, 19, 22, 24	10 66

The 1941 collections were begun on April 22, on which date only one bluegill revealed a marginal annulus. On April 24, 26, and 28, and May 1 and 3 increasing percentages of the scales had a marginal annulus. After May 3 all samples bore a marginal annulus with some growth beyond the annulus.

The annulus was just inside the edge on the majority of the scales of fish taken from Budd Lake (Zone 2), May 17–18, 1939, but only a few of those caught on May 17, 1940, had an annulus. All scales collected on June 19, 1939 and 1940, showed an annulus with a marginal growth.

On the scales secured in Round Lake (Zone 2) on May 26–28, 1939, the annulus was just inside the margin. In the next collection, made on June 21–23, an annulus was present within a wide band of growth on all fish. In 1940, scales collected on May 20 had no annulus, but all of those taken on June 19 exhibited an annulus inside the scale margin.

The annulus was on the edge of some scales collected in North Manistique Lake (Zone 3) on June 25, 1939, and a few scales had a slight marginal growth. In 1940 a collection made here on May 22 gave no indication that an annulus had been laid down. On June 24, when the next sample was obtained, the annulus had been formed on all specimens, with a slight marginal growth on some.

In Bass Lake (Zone 3) the annulus was obvious on all specimens when a collection was made on June 25, 1939. All scales taken on July 28–29 showed a band of marginal growth that was distinctly wider than that on the scales of the previous collection. In 1940 a sample was taken on May 24, at which time no annulus was apparent. When the next collection was made, on June 25, the annulus had formed on all scales.

Collections were made on July 1–3, 1939, in Crooked Lake (Zone 3). The annulus was to be seen on the edge of the scales. In 1940 a collection made in May showed no annulus present. All scales collected on June 26, 1940, had an annulus near the edge.

On the scale samples secured from Lake Fannie Hooe (Zone 3) on July 4–6, 1939, the annulus was just inside the edge of all except a few, which had a fair amount of marginal growth. No annulus was present on any of the scales collected on May 27–28, 1940. The next collection, taken on June 27–28, showed an annulus near the edge of all scales.

Additional scattered material was obtained through samples of scales taken in the springs of 1939 and 1940 from other lakes that were visited during the investigation of other problems. Others were obtained from Standard Lake (Zone 2) during May and June, 1939, and from Ford Lake (Zone 2) in May, 1939, and May, 1940. Samples were kept from fish caught in June, 1940, during a survey of certain lakes in Menominee County (Zone 3). In all these samples the indicated time of annulus formation agreed with the findings for the selected lakes in the same region.

The data on the bluegills of Pasinski Pond not only provide information concerning the time of annulus formation but also yield strong evidence in support of the belief that only one annulus is formed each year. The annulus formed on the scales of bluegills (the only game fish present) in the pond (Zone 1) between April 23 and 29, 1939. None of the scales collected on April 23 had a marginal annulus, but the year mark was evident on the scales of all fish taken on April 29. It was impossible to continue the observations here beyond the growing season of 1939 because this pond suffered a complete winterkill in February, 1940. This event was particularly unfortunate since the fish were of known age and many had been jaw-tagged.

The second-year growth of these fish (all known to be yearlings) up to different times of capture in the growing season is described as the percentages of the average "expected" growth for the entire growing season of 1939. This average full-season growth, derived from the measurements of the scales of 164 bluegills taken at the time of the winterkill is indicated by the heavy vertical line on the graph (Fig. 2). The range of length and the number of specimens on which each percentage is based are shown by the frequency curves. The mean growth of each collection is represented by a broken vertical line.

It will be seen that on April 23 no fish had an annulus, but an annulus with a small amount of marginal growth was present in all specimens in the collection of April 29. A steady increase in the percentage of the annual growth completed occurred in the succeeding collections. Though the range of variation increased somewhat during the season, none of the fish taken in May, June, or July had the annulus sufficiently close to the margin to indicate recent formation. By July approximately 85 per cent of the "expected" growth for

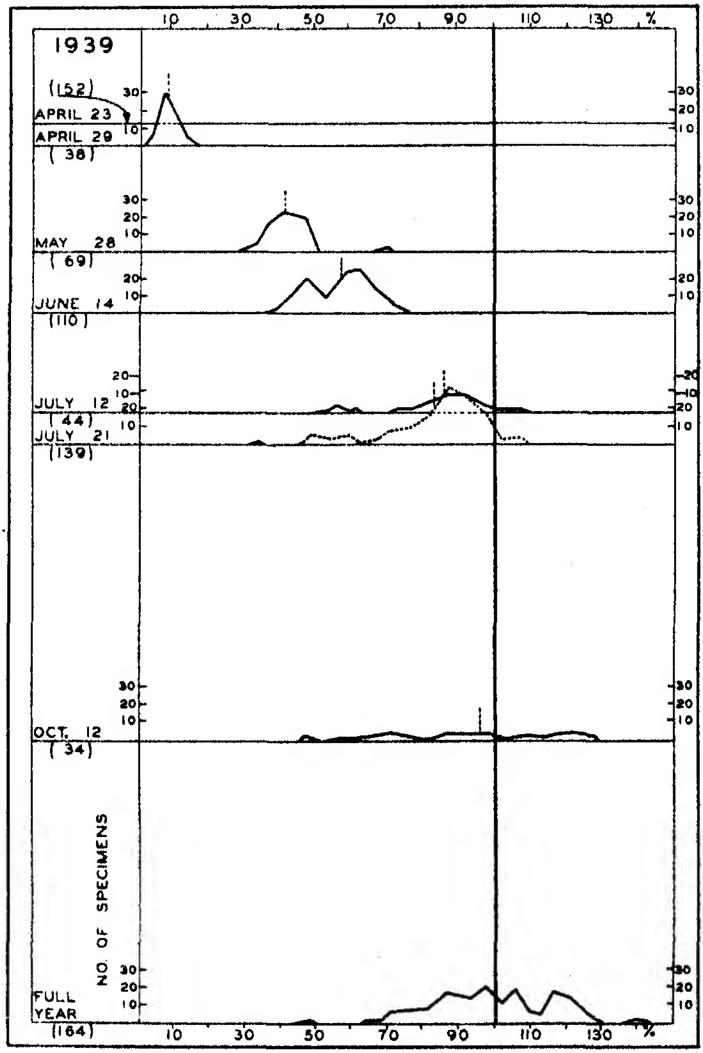

FIG. 2. Percentage of "expected" annual scale growth completed on different dates by yearling bluegills from Pasinski Pond in 1939. Number of specimens in parentheses. Heavy solid line indicates the mean of the full year's growth. Broken lines indicate the means of the individual collections

the season had been completed. In October a small collection showed that 96 per cent of the "expected" growth had been attained. When the fish were killed in February, 1940, they had not yet formed the second annulus, but undoubtedly would have completed this structure in the spring had they lived.

The relatively small variation in the amount of the marginal growth on the scales of the Pasinski Pond bluegills caught on the same date and the increase of this growth during the summer are illustrated by the photographs in Plates II–IV. The scales that are pictured were taken at random from the collections of the dates listed.

The data for other waters as well as for Pasinski Pond indicate uniformly that only one annulus is formed each year. For a number of species and in several lakes the relative amounts of the annual scale growth outside the marginal annulus were calculated for each date of sampling. Table III shows the typical results of the calculations. The amount of growth at any date is given as the percentage of the "expected" full-season growth for fish in that particular year of life. The "expected" annual scale growth was determined as the mean of the full-season increments of the scale for each year of life for all specimens that had survived beyond that year. For example, the average scale growth for the first year of life was based on the growth made in that year by all fish in the collection one year old and older, and that for the second year was based on all fish two years old and older, and so on. The percentage of scale growth completed at the time of capture was obtained by dividing the average growth outside the annulus by the average full-season growth expected for fish in the same year of life. The table shows that the annulus formed between certain dates and that in successive collections lay farther and farther within the scale margin. It may be seen also from Table III that in Deep Lake, as in Pasinski Pond, all annuli were completed within a very short period. It is believed that the annulus forms rapidly in all lakes.

The time of annulus formation is correlated roughly with the mean monthly air temperatures. At comparable dates the springs of 1939 and 1941 were warmer than the spring of 1940, and the annulus formed earlier in 1939 and 1941 than in 1940. Since water temperature and air temperature are correlated rather closely, it is to be expected that the water would become warmer earlier in a warm

TABLE III

SCALE GROWTH OUTSIDE MARGINAL ANNULUS, AS THE PERCENTAGE OF THE EXPECTED TOTAL GROWTH FOR THE GIVEN YEAR

The average expected scale growth for a particular year of life was based on average measurements of the scale growth of all fish that had completed that year of life. The data are based on collections from Deep Lake.

Species and date	Age group						
	I	II	III	IV	V	VI	VII
Bluegill							
February 4, 1939	...	...	...	...	0 (2)	...	...
April 27, 29	...	...	...	0 (2)	0 (5)	...	...
May 17, 19, 21, 27	...	...	17 (10)	20 (25)	33 (14)	44 (1)	...
June 5, 8, 13, 20, 28	...	25 (1)	35 (17)	38 (27)	40 (9)	...	...
July 2, 5, 7, 13, 24, 26	44 (2)	47 (15)	57 (10)	51 (17)	61 (3)	...	...
August 2, 4	...	78 (1)	78 (3)	64 (6)	...	...	...
April 29, 1940	...	...	0 (1)	...	...	...	...
May 2, 8	...	...	0 (4)	0 (3)	...	...	...
May 10	...	0 (2)	*0.8 (6)	0 (2)	...	...	...
May 13, 14	...	...	5 (11)	7 (5)	13 (7)	12 (6)	0 (1)
May 20, 22, 27	...	...	...	15 (5)	24 (5)	35 (3)	...
June 14	115 (2)	37 (5)	30 (12)	32 (2)	44 (1)	...	...
Pumpkinseed							
April 27, 1939	...	...	...	...	0 (1)	...	...
May 17, 21, 27	...	...	...	...	27 (20)	...	...
June 5, 8, 13, 20, 28	...	...	...	...	53 (7)	...	...
July 2, 12, 13, 24	62 (3)	51 (10)	50 (2)	62 (5)	103 (2)	...	...
August 2	...	...	...	...	77 (2)	...	...
April 25, 29, 30, 1940	...	...	0 (7)	0 (5)	0 (4)	0 (4)	...
May 2, 8	...	...	0 (6)	0 (4)	0 (9)	0 (4)	0 (1)
May 10	...	...	*1 (2)	*3 (2)	...	...	0 (1)
May 13, 14	...	...	*10 (7)	13 (5)	4 (1)	...	...
May 20, 22, 27	...	...	27 (2)	34 (4)	36 (3)	...	...
June 14	...	38 (2)	49 (15)	54 (1)	...	...	...

* Some with or without growth

spring than in a cold one. When the lakes of the southern part of the Lower Peninsula have become sufficiently warm to permit the resumption of fish growth, the lakes in the Upper Peninsula are barely ice-free. As the temperatures gradually increase in the north, growth of the fish in these lakes is finally resumed, with the resultant annulus formation. Since the local temperature conditions vary

considerably from year to year, and since the isotherms form irregular patterns, it was found impracticable to delimit on the basis of isotherms the zones or sections which are needed for a further analysis of the variations throughout the state in the time of annulus formation. The lines of separation of three general areas or zones were set somewhat arbitrarily as Town Line 10 North and the Straits of Mackinac. Zone 1 extends from the southern boundary of the state north to Town Line 10; Zone 2 covers the Lower Peninsula north of this line; and Zone 3 comprises the entire Upper Peninsula (Fig. 1). It must be remembered that the temperatures decrease gradually toward the north, and it has been found that the time of annulus formation shows a similar gradient, without the abrupt discontinuities that zones are likely to suggest.

It is estimated that in an "average" year the annulus is usually completed in Zone 1, the southern one third of the Lower Peninsula, by the middle of May; in Zone 2, the northern two thirds of the Lower Peninsula, by the first part of June; and in Zone 3, the Upper Peninsula, by the end of June. The date of actual completion will vary somewhat according to temperature conditions in different localities and in different years.

SUMMARY

1. The investigation of annulus formation on the scales of some of the game fishes of Michigan was begun in 1939 under the sponsorship of the Michigan Institute for Fisheries Research.

2. Scale samples were collected at regular intervals from seven lakes and a pond; additional samples were taken from other lakes in connection with other investigations.

3. Temperature appears to be the primary factor in annulus formation.

4. Spawning was found to have little or no effect on the time of annulus formation.

5. Food is ordinarily of secondary importance as a factor in the time of annulus formation. A severe scarcity of food, or an abrupt change in the availability of food, may make it a primary factor.

6. The mean temperatures of the days on which the scales in the collections first showed annuli were 53° F. in 1940 and 52° F. in 1941. The mean temperatures of the first days on which the majority of the scale samples showed an annulus were 58° F. in both 1940 and 1941.

7. The annulus formed earlier in 1939 and 1941 than in 1940. The earlier formation in 1939 and 1941 was correlated with the higher temperatures at corresponding dates in those two years.

8. The time of annulus formation was progressively later from the southern part of Michigan to the northern part.

9. The state was divided arbitrarily into three zones: Zone 1, roughly the southern one third of the Lower Peninsula; Zone 2, the northern two thirds of the Lower Peninsula; and Zone 3, the Upper Peninsula. In all but exceptionally cold years the formation of the annulus may be expected to be completed in Zone 1 by the middle of May; in Zone 2, by the first part of June; and in Zone 3, by the end of June. Annual fluctuations in temperature may bring about some variation in the date of formation of the year mark.

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APPENDIX

DETAILED DATA ON THE TIME OF ANNULUS FORMATION ON THE SCALES OF MICHIGAN GAME FISHES

The data of Table III on the time of annulus formation on the scales of Michigan game fishes are not presented by species. The following data show definitely that the different species formed the year mark simultaneously as they started to grow in the spring.

CLEAR LAKE, JACKSON COUNTY

Data for 1939

Annulus not yet formed at the margin:
- January 19: 2 black crappies
- February 25, 28: 15 bluegills

Marginal annulus formed in some specimens:
- April 28: 6 perch with annuli, 2 without; 2 bluegills without; 1 rock bass without; 1 black crappie with, 1 without

Annulus formed on all scales:
- June 1: 12 perch, 6 largemouth bass, 19 bluegills, 2 rock bass, 16 pumpkinseeds, 4 black crappies
- July 15: 6 perch, 5 largemouth bass, 13 bluegills, 8 pumpkinseeds
- December 31: 6 bluegills, 8 black crappies

Data for 1940

Marginal annulus formed in some specimens:

May 7: 3 largemouth bass without annuli; 2 bluegills with, 22 without; 10 pumpkinseeds with, 4 without; 1 green sunfish × bluegill with, 2 without

Annulus formed on all scales:

June 6: 17 perch, 6 largemouth bass, 9 bluegills, 9 rock bass, 6 pumpkinseeds, 4 black crappies, 2 green sunfish

BUDD LAKE, CLARE COUNTY

Data for 1939

Marginal annulus formed in some specimens:

May 17: 21 perch with annuli, 9 without; 24 bluegills with; 5 pumpkinseeds with, 4 without; 3 largemouth bass with, 1 without; 2 rock bass with; 1 black crappie with; 3 pumpkinseed × green sunfish with

Annulus formed on all scales:

June 19: 52 perch, 29 bluegills, 70 pumpkinseeds, 13 largemouth bass, 1 green sunfish, 4 rock bass, 3 black crappies, 2 bluegill × pumpkinseed, 1 pumpkinseed × green sunfish

October 28: 1 perch, 3 bluegills, 6 pumpkinseeds, 2 largemouth bass, 5 rock bass

Data for 1940

Marginal annulus formed in some specimens:

May 17: 7 perch with annuli, 20 without; 1 bluegill with, 31 without; 3 pumpkinseeds with, 5 without; 6 largemouth bass without; 1 green sunfish without; 9 rock bass with, 10 without; 2 black crappies without; 5 pumpkinseed × green sunfish without

Annulus formed on all scales:

June 19: 14 perch, 16 bluegills, 15 pumpkinseeds, 8 largemouth bass, 1 green sunfish, 3 rock bass

ROUND LAKE, EMMET COUNTY

Data for 1939

Annulus formed on all scales:

May 25: 10 pumpkinseeds, 5 rock bass

June 24: 25 pumpkinseeds, 19 bluegills, 21 perch, 12 rock bass

October 20: 1 pumpkinseed, 3 bluegills, 2 rock bass, 1 largemouth bass

Data for 1940

Annulus not yet formed at margin:

May 20: 6 pumpkinseeds, 4 rock bass, 3 largemouth bass

Annulus formed on all scales:

June 21: 22 pumpkinseeds, 18 bluegills, 2 perch, 7 rock bass, 1 largemouth bass

NORTH MANISTIQUE LAKE, LUCE COUNTY

Data for 1939

Annulus formed on all scales:
- June 26: 32 rock bass, 27 perch, 9 walleyes, 8 smallmouth bass
- July 28: 43 rock bass, 61 perch, 6 walleyes, 1 smallmouth bass
- September 7: 5 rock bass, 8 perch, 8 walleyes
- October 21: 2 rock bass, 7 perch, 6 walleyes

Data for 1940

Annulus not yet formed at margin:
- May 23: 28 rock bass, 18 perch, 7 walleyes

Annulus formed on all scales:
- June 24: 8 rock bass, 16 perch, 4 walleyes
- July 21: 16 rock bass, 21 perch, 6 walleyes, 6 smallmouth bass

BASS LAKE, MARQUETTE COUNTY

Data for 1939

Annulus formed on all scales:
- June 25: 14 pumpkinseeds, 2 pumpkinseed × bluegill
- July 4: 8 bluegills, 16 pumpkinseeds, 1 perch
- July 29: 41 bluegills, 19 pumpkinseeds, 6 perch, 3 walleyes, 3 largemouth bass
- September 15: 3 bluegills, 1 pumpkinseed, 2 walleyes
- October 22: 8 bluegills, 6 perch, 1 largemouth bass, 1 smallmouth bass

Data for 1940

Annulus not yet formed at margin:
- May 24: 17 bluegills, 10 pumpkinseeds, 4 perch, 1 walleye, 3 largemouth bass, 1 smallmouth bass

Annulus formed on all scales:
- June 25: 10 bluegills, 7 pumpkinseeds, 5 perch, 6 walleyes, 1 largemouth bass
- July 24: 30 bluegills, 7 pumpkinseeds, 18 perch, 2 walleyes, 1 largemouth bass, 1 smallmouth bass

CROOKED LAKE, GOGEBIC COUNTY

Data for 1939

Annulus formed on all scales:
- July 3: 32 perch, 11 bluegills, 9 smallmouth bass, 5 largemouth bass, 2 black crappies, 9 pumpkinseeds
- July 31: 16 perch, 4 bluegills, 9 smallmouth bass, 6 largemouth bass, 1 black crappie, 2 pumpkinseeds
- August 26: 54 perch, 8 bluegills, 1 smallmouth bass, 6 largemouth bass, 1 black crappie
- October 23: 9 perch, 2 bluegills, 2 smallmouth bass, 1 pumpkinseed

Data for 1940

Annulus not yet formed at margin:
  May 26: 22 perch, 1 bluegill, 1 smallmouth bass, 6 black crappies
Annulus formed on all scales:
  June 27: 15 perch, 2 bluegills
  July 27: 38 perch, 6 bluegills, 3 largemouth bass, 2 black crappies

LAKE FANNIE HOOE, KEWEENAW COUNTY

Data for 1939

Annulus formed on all scales:
  July 4–6: 19 rock bass, 8 perch, 3 smallmouth bass, 1 bluegill
  August 2–4: 21 rock bass, 27 perch
  August 30: 4 rock bass, 7 perch
  October 24: 1 rock bass, 1 perch

Data for 1940

Annulus not yet formed at margin:
  May 27–28: 4 rock bass, 7 perch, 1 bluegill
Annulus formed on all scales:
  June 27: 10 rock bass, 8 perch
  July 27–29: 19 rock bass, 20 perch

DEEP LAKE, OAKLAND COUNTY

Data for 1939

Annulus not yet formed on margin:
  February 2: 2 bluegills
  April 27: 5 rock bass, 1 pumpkinseed, 2 bluegills
  April 29: 5 bluegills
Annulus formed on all scales:
  May 17: 14 rock bass, 15 pumpkinseeds, 9 bluegills
  May 19: 1 pumpkinseed, 2 bluegills
  May 21: 1 rock bass, 1 pumpkinseed, 20 bluegills
  May, June, July, August: 10 rock bass, 46 pumpkinseeds, 144 bluegills

Data for 1940

Annulus not yet formed at margin:
  April 24: 1 rock bass
  April 25: 1 pumpkinseed
  April 29: 7 rock bass, 4 pumpkinseeds, 1 bluegill
  April 30: 2 rock bass, 15 pumpkinseeds, 2 largemouth bass
  May 2: 5 rock bass, 16 pumpkinseeds, 3 bluegills, 2 largemouth bass
  May 8: 16 rock bass, 7 pumpkinseeds, 4 bluegills
Marginal annulus formed in some specimens:
  May 10: 2 rock bass with annuli, 14 without; 2 pumpkinseeds with, 11 without; 1 bluegill with, 9 without; 1 largemouth bass without
  May 13: 7 rock bass with annuli, 1 without; 8 pumpkinseeds with; 22 bluegills with, 2 without

May 14: 7 rock bass with annuli, 1 without; 7 pumpkinseeds with, 1 without; 7 bluegills with, 1 without

Annulus formed on all scales:

May 20: 4 rock bass, 2 pumpkinseeds, 5 bluegills
May 22: 1 rock bass, 4 pumpkinseeds, 9 bluegills
May 27: 1 rock bass, 4 pumpkinseeds, 2 bluegills, 2 largemouth bass
June 14: 5 rock bass, 18 pumpkinseeds, 22 bluegills

Data for 1941

Marginal annulus formed in some specimens:

April 22: 2 pumpkinseeds without annuli; 1 bluegill with, 16 without
April 24: 2 rock bass with annuli, 8 without; 6 pumpkinseeds with, 17 without; 4 bluegills with, 14 without
April 26: 5 pumpkinseeds with annuli, 9 without; 8 bluegills with, 16 without
April 28: 5 rock bass with annuli; 8 pumpkinseeds with, 5 without; 12 bluegills with, 4 without
May 1: 3 rock bass with annuli; 11 pumpkinseeds with, 2 without; 6 bluegills with, 1 without
May 3: 4 rock bass with annuli; 11 pumpkinseeds with; 9 bluegills with, 1 without

Annulus formed on all scales:

May 5: 2 rock bass, 5 pumpkinseeds, 3 bluegills
May 7: 2 rock bass, 4 pumpkinseeds, 2 bluegills
May 9: 1 rock bass, 2 bluegills
May 12: 2 rock bass, 4 pumpkinseeds, 2 bluegills
May 16–24: 7 rock bass, 17 pumpkinseeds, 23 bluegills

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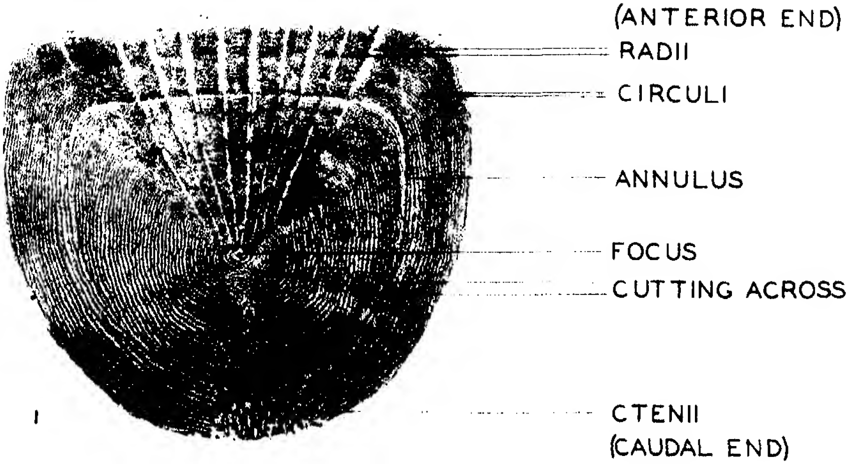

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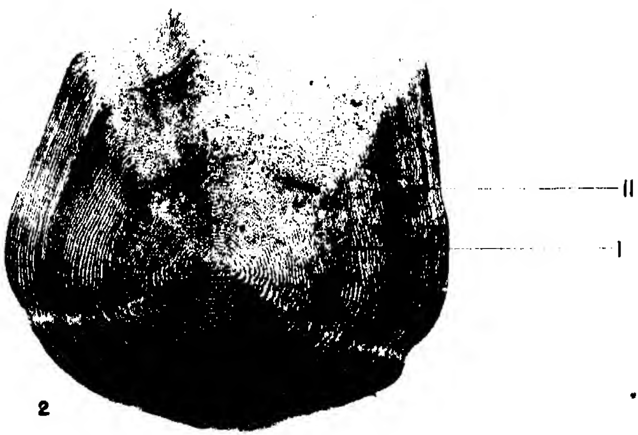
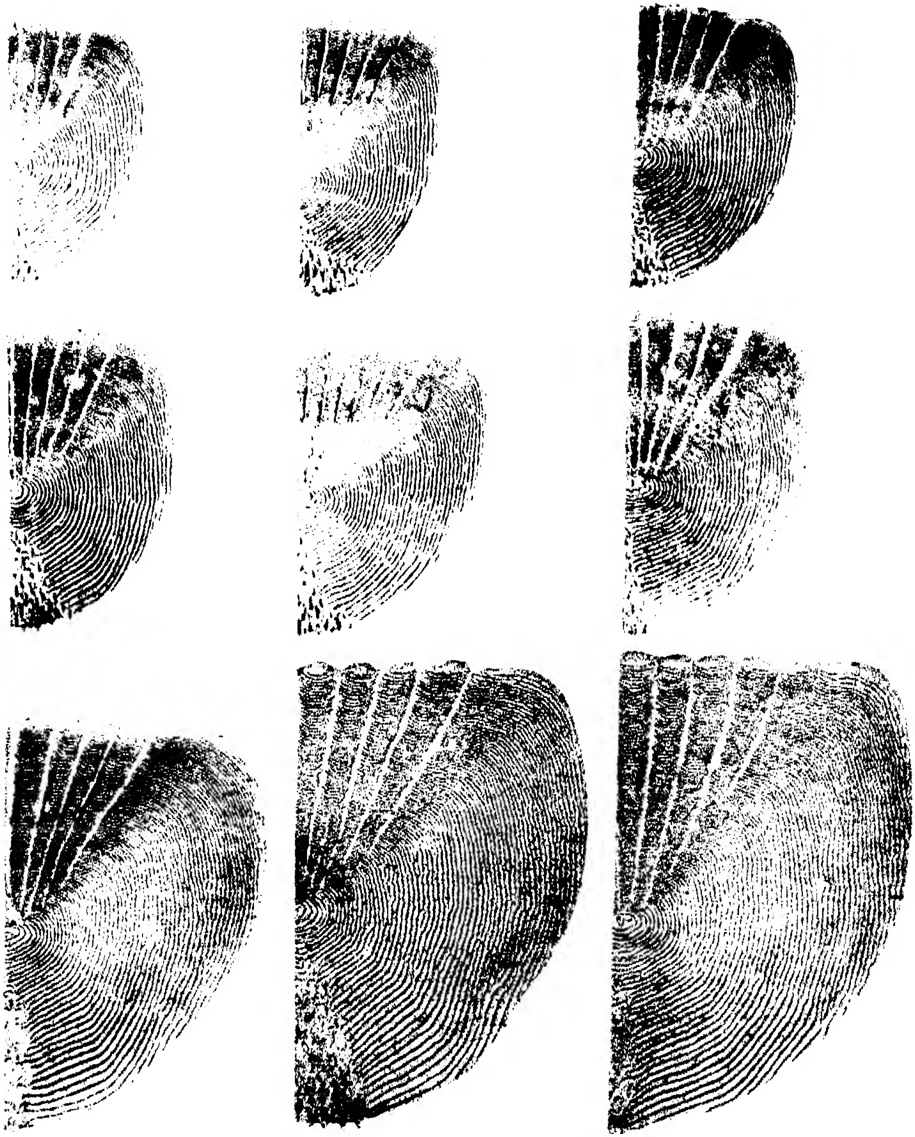


2

FIG. 1. Ctenoid scale from a bluegill 4¼ inches long. Age one year

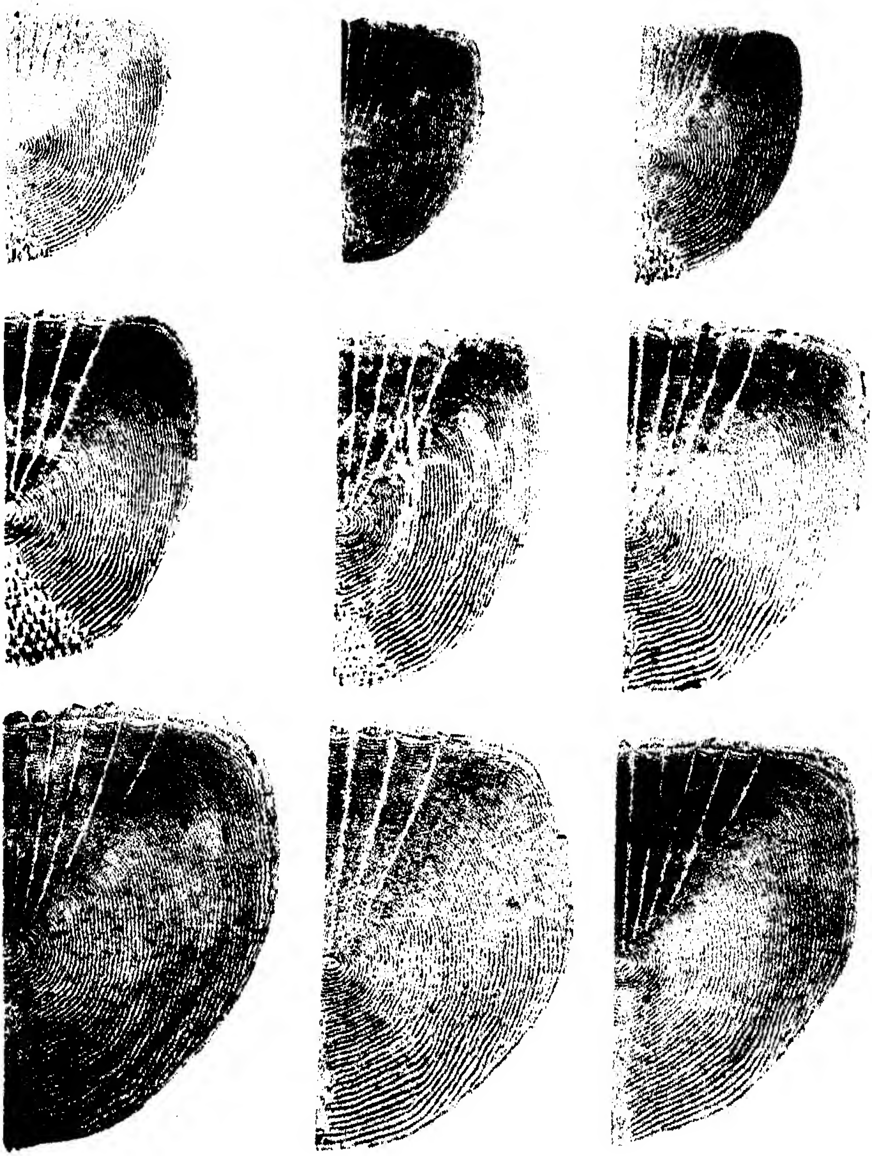
FIG. 2. Cycloid scale from a cisco 11 inches long. Age two years

(Annuli indicated by Roman numerals)

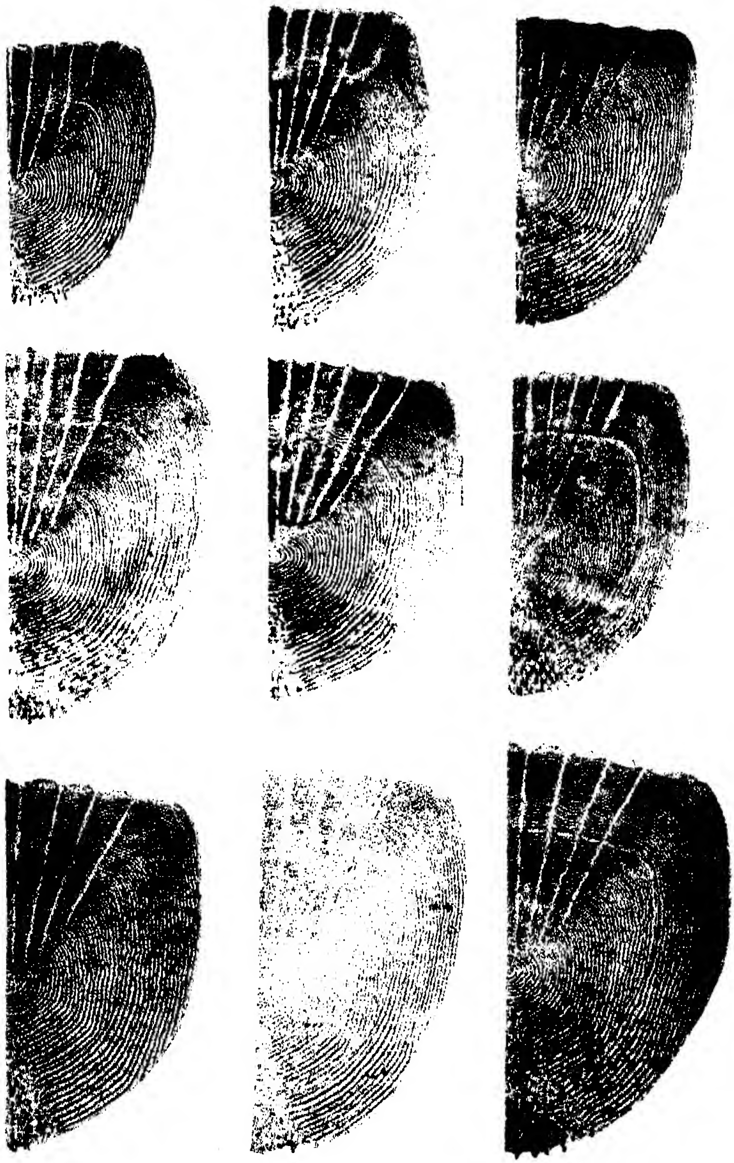


Scales of bluegills (size range, $2\frac{7}{8}$–$4\frac{1}{4}$ inches, total length) taken from Pasinski Pond, Livingston County, Michigan, April 23, 1939. No annulus present.

(All photographs in Plates II–IV taken at a magnification of 44.3)



Scales of bluegills (size range, 2¾–4¼ inches, total length) taken from Pasinski Pond April 29, 1939. Annulus at edge



Scales of bluegills (size range, $2\frac{3}{4}$–$4\frac{1}{4}$ inches, total length) taken from Pasinski Pond, June 14, 1939. Annulus well inside margin of growth

A TEST OF FECUNDITY OF THE GARTER SNAKE *THAMNOPHIS SIRTALIS SIRTALIS* (LINNAEUS) IN THE YEAR FOLLOWING THE YEAR OF INSEMINATION *

FRIEDA COBB BLANCHARD

IN THE routine of my genetical studies of the garter snake *Thamnophis sirtalis sirtalis* a female has been regarded as safe material for controlled mating in the spring if she has been isolated from males since before the birth of her brood in the preceding summer. The technique has been based on the supposition that sperm do not live in the female from one spring to the next, that one insemination does not produce two broods, in successive years.

There is good evidence that some females caught in the fall are already impregnated and may bear young in the following summer without a spring mating [1] — that is, that sperm or embryos may hibernate within the female — yet in the work of many years no reason has been seen for believing that two broods, a year apart, could result from one insemination. In the earlier years of the work it happened more than a dozen times that a female which had young one summer did not mate in the following spring, and each time she was barren. In no instance was a female which was isolated previous to the birth of her young known to have another brood without another copulation. But because these instances were scattered through the years and the females involved were heterogeneous if considered as a group, and because of the doubts cast on breeding data as a result of the recent discovery of "delayed fertilization" in some snakes, a planned test of fecundity in the second year was made.

* Paper No. 805 from the Botanical Garden and the Department of Botany of the University of Michigan.

[1] Blanchard, F. N. and Frieda Cobb, "The Inheritance of Melanism in the Garter Snake *Thamnophis sirtalis sirtalis* (Linnaeus), and Some Evidence of Effective Autumn Mating," *Pap. Mich. Acad. Sci., Arts, and Letters,* 26 (1940): 177–193. 1941.

Thirty-five females which had been caught and isolated shortly before their young were born in the summer of 1940 were continued in isolation during the following year, 1941. Of the thirty-five, seventeen came from the vicinity of Cheboygan, Michigan, twelve from Long Point, Ontario, and the other six were of various local origins. In length they ranged from 660 mm. to 930 mm.; only seven were under 700 mm. This group of females, isolated since before the birth of their young in the summer of the preceding year, proved to be entirely barren in 1941. There is of course a remote possibility that in each of the thirty-five instances the 1940 brood itself was the second of two broods following a single insemination in the spring of 1939; but this is extremely unlikely. The test seems to give good evidence that in *Thamnophis sirtalis sirtalis* two broods are not produced by a single insemination and that females isolated before the birth of their young may safely be used at any time thereafter for controlled mating.

Although females have been known to produce young after a spring in which no mating occurred, presumably from an insemination of the preceding autumn, nothing has been known about the frequency of effectual autumn mating in nature. With this question in mind, an attempt was made in October, 1940, to catch females just before their hibernation, when they had had all possible chance for fall mating. Eight females caught at Long Point during the first two weeks of October, 1940, were kept in isolation until autumn of 1941. Of the eight, five bore young, and three (which were small, but probably mature) did not. This ratio indicates that autumn mating is common, perhaps usual.

Whether or not fall mating influences or obviates mating in the following spring has not been determined, but the ratios of color patterns (black and striped) in the five broods just mentioned throw some light on this matter, and at the same time help to explain the odd color ratios recorded by Logier[2] in broods of wild females at Long Point. Though melanism is a simple Mendelian recessive character,[3] the broods borne by black females which mate in the wild give ratios of striped to black snakelings which do not even suggest Mendelian ratios: in a mixed brood there may be only one

[2] Logier, E. B. S., "Melanism in the Garter Snake, *Thamnophis sirtalis sirtalis*, in Ontario," *Copeia*, 172: 83–84. 1929; "Some Additional Notes on Melanism in *Thamnophis sirtalis sirtalis* in Ontario," *Copeia*, 1: 20. 1930.

[3] See Blanchard and Blanchard, *op. cit.*

black among the striped snakelings, or they may all be black except one, or there may be any ratio between these extremes. In explanation of this odd circumstance it has been suggested that the females mate more than once, and that a brood may represent more than one male, for, unless the males happened to be alike in genetical constitution, this would result in quite irregular ratios, like those which actually occur. But in the spring, females under observation seem to avoid more than one copulation (or perhaps the males avoid courting a female recently impregnated). Therefore it has been suggested (without supporting observations) that the wild females may mate in the autumn and again in the spring, thus producing broods with meaningless, irregular ratios.

If the irregular ratios do result from an autumn mating followed by another in the spring, females caught after opportunity for fall insemination and prevented from mating in the spring might be expected to bear broods showing Mendelian segregation; and this is what happened in the five instances just mentioned. One of the five females was black, and her progeny were all black, indicating that her mate also was black. Of the four striped females, two gave broods entirely of striped young, showing that each was homozygous for the factor for stripe or, if heterozygous, that the male involved was homozygous. The other two striped females gave mixed broods, the ratio of striped to black young (3 striped : 5 black; 4 striped : 3 black) being sufficiently close to a 1 : 1 ratio to indicate that both females were heterozygous and mated with a black male. These five broods, therefore, not only show the prevalence of mating in the fall, but indicate that in nature this does not interfere with spring mating, and support the belief that the confused color ratios in wild broods are the result of an autumn mating followed by one in the spring.

If the preceding explanation of irregular color ratios is correct (that a brood may represent two males, one copulating in the autumn, the other in the spring), it is evident that though insemination may occur in the fall the eggs are not fertilized until after the spring insemination. That sperm, rather than embryos, hibernate within the female is indicated also by the fact that the five broods resulting from mating in the autumn, without subsequent spring mating, were not born earlier in the following summer than were broods from spring copulations.

SUMMARY

1. That young are not produced in successive summers by a single insemination is shown by the fact that no broods were borne in 1941 by thirty-five females which were caught and isolated before their young were born in 1940.

2. That effective autumn mating is common in nature is shown by the fact that five out of eight females caught and isolated in October, 1940, produced broods in the summer of 1941 without spring mating. The three which were barren were small but probably mature.

3. The broods borne by these five females, caught at Long Point, Ontario, in the fall, showed Mendelian ratios of striped and black young, though the broods of females caught in spring at the same place do not. This supports the suggestion that the irregular ratios in nature result from two copulations, that in the spring being preceded by one in the fall.

4. If this is the correct explanation of the irregular color ratios in nature, it follows that though insemination may take place in the fall, fertilization does not occur until spring. This is indicated also by the fact that the five broods from fall matings alone were not born earlier than broods from matings of the following spring.

UNIVERSITY OF MICHIGAN

FEMALE ALLOTYPE OF *LANDANA SPINOSA* PETRUNKEVITCH

ARTHUR M. CHICKERING

WHILE conducting field studies on Barro Colorado Island, Canal Zone, in August, 1938, Dr. Alexander Petrunkevitch collected two male specimens of a very remarkable species. He made one of these spiders the type of *Landana spinosa* (1939) and extended his study to include internal anatomy. Examination of the internal and external anatomy of these specimens led Dr. Petrunkevitch to reinvestigate the anatomy of specimens of *Archaea workmanni* (O. P. Cambridge) from Madagascar. This further led to the reconsideration of the status of the family Archaeidae and the reassignment of *Landana* to this family, where it was originally placed by Simon (1883). On the basis of marked differences in structure between the sexes in *Landana* and the fact that *L. cygnea* builds geometric orb webs, Simon later (1895) placed the genus among the Argiopidae, near *Meta*.

I collected both sexes of *Landana spinosa* Petrunkevitch on Barro Colorado Island, Canal Zone, in 1934, 1936, and 1939. The males were assigned to the genus *Landana*, but they were not carefully studied at that time. The females were wrongly assigned to a genus in the Argiopidae. These have now been definitely matched up with the males, and one is described below as the allotype. Soon after the publication of Petrunkevitch's paper (1939) on *Landana* I sent specimens of my females to Miss Elizabeth B. Bryant, Museum of Comparative Zoölogy, Harvard College, for her opinion regarding their placement. Miss Bryant almost immediately recognized them as females of *L. spinosa*.

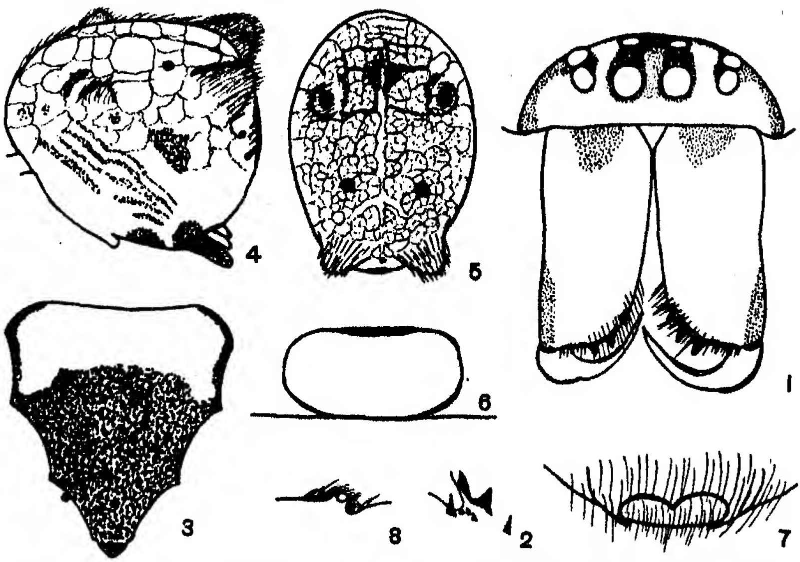
DIAGNOSIS

(Figures 1–8)

Female allotype. — Total length from posterior abdominal humps to anterior end of cephalothorax 4.16 mm. Carapace 1.96 mm. long, 1.35 mm. wide at widest part between second and third coxae, 0.73

mm. wide at level of posterior eyes. Thoracic groove lacking, but in its place a transverse depression. Head and thorax well separated by cephalic grooves. Gently arched from posterior eyes to cephalic depression.

Eyes. — Eight in two rows, heterogeneous (Fig. 1); AME alone diurnal. Two rows of almost equal length. Seen from above, posterior row slightly procurved, anterior row strongly recurved. Ratio of



EXTERNAL ANATOMY OF *LANDANA SPINOSA* PETRUNKEVITCH
(Figures 1–8)

1. Front view of chelicerae, eyes, and clypeus
2. Teeth along margins of fang groove
3. Sternum
4. Abdomen, lateral view
5. Abdomen, dorsal view
6. Epigynum, viewed somewhat posteriorly
7. Epigynum, viewed ventrally
8. Epigynum, in profile

eyes AME : ALE : PME : PLE = 4 : 3 : 3 : 3. AME separated from one another by their diameter, from ALE by their diameter. PME separated from one another by their diameter, from PLE by twice their diameter. Laterals separated by a line. Central ocular quad-

rangle wider in front than behind in ratio of 11 : 9, longer than wide in front in ratio of 13.5 : 11. Width of clypeus a little greater than diameter of AME.

Chelicerae. — Of normal size, slightly gibbous in front at proximal end just below clypeus, basal segment 0.94 mm. long, with a moderately developed boss, insertion apparently normal. Promargin of fang groove with three teeth of moderate size, the last two next to base of fang connected at their bases; retromargin with one tooth of moderate size near base of fang, followed by a row of three minute teeth out of line (Figs. 1–2). A paratype has four of these minute teeth. Fang of moderate size and evenly curved.

Maxillae. — Longer than wide in ratio of 20 : 14, widest near distal end, nearly parallel, with well-developed scopulae along medial borders and inner distal angle; well-developed marginal serrulae; rostrum not abnormally long as described for male; nearly straight outer margins.

Lip. — Wider than long in ratio of 12 : 9, distal margin somewhat rebordered and gently curved, reaches less than half the length of maxillae.

Sternum. — Scutiform, longer than wide in ratio of 31 : 27, widest between intervals separating first and second coxae, with many long bristles, extending to a blunt termination between posterior coxae, which are separated by their radius (Fig. 3).

Legs. — 1243. Tibial index of first leg 10, of fourth leg 15.

	Femora	*Patellae and tibiae*	*Metatarsi*	*Tarsi*	*Totals*
		(All measurements in millimeters)			
1.	2.66	2.82	2.10	0.86	8.44
2.	2.08	2.32	1.59	0.70	6.69
3.	1.23	1.22	0.68	0.48	3.61
4.	1.96	1.59	1.08	0.49	5.12

Spines. — First leg: femur, dorsal 1 (weak) – 0 – 0, prolateral 0 – 1 – 1 (weak) – 1, retrolateral 0 – 0 – 1, ventral 0; patella, dorsal 1 (weak) – 1, elsewhere 0; tibia, dorsal 1 – 0 – 1, prolateral 1 – 1 – 1, retrolateral 1 – 1 – 1, ventral 0 – 1 – 1; metatarsus, dorsal 1 – 0 – 0, prolateral 1 – 0 – 0, retrolateral 0 – 1 – 1 – 0, ventral 1 (weak) – 1 (weak) – 0 – 0. Second leg: femur, dorsal 0, prolateral 0 – 0 – 1, retrolateral 0 – 0 – 1, ventral 0; patella, same as in first leg; tibia, dorsal same as in first leg, prolateral 1 (weak) – 0 – 1, retrolateral 1 – 1,

ventral 0 – 0 – 1; metatarsus, dorsal 1 – 0 – 0, prolateral 1 – 1 – 0 – 0, retrolateral 0 – 1 – 0, ventral 1 (weak) – 1 (weak) – 0 – 0. Third leg: femur, dorsal 0, prolateral 0 – 0 – 1, retrolateral 0 – 0 – 1, ventral 0; patella, dorsal 1 (weak) – 1, elsewhere 0; tibia, dorsal 0, prolateral 0 – 1, retrolateral 1 – 0, ventral 0 – 1 – 0; metatarsus, dorsal 1 – 0, prolateral 1 (middle), retrolateral 0, ventral 1 – 0. Fourth leg: femur, dorsal 0, prolateral 0 – 0 – 1, retrolateral 0 – 0 – 1, ventral 0; patella, dorsal 1 (weak) – 1, prolateral 0, retrolateral 0, ventral 0; tibia, dorsal 1 – 0, prolateral 1 – 0 – 1, retrolateral 0 – 0 – 1, ventral 0. Trichobothria and claws essentially as in male.

Abdomen. — Essentially as in male (Figs. 4–5). Two pairs of dorsal tubercles, of which posterior ones are much the larger. A single tracheal spiracle just anterior to well-developed colulus. Spinnerets as in male. Anal tubercle prominent, flattened.

Color in alcohol. — Essentially as in male except that colored areas are larger and more intense. Dusky submarginal stripes on cephalothorax darker in female and extending to lateral eyes, with a break at cephalic groove and another just posterior to lateral eyes. Elongate triangular dusky spot, which occurs in most males directly in front of the thoracic pit, in female extending throughout eye region, where gray color is more or less broken into patches. Posterior half of sternum bright red, with narrow extensions of this color anteriorly along margin. Lateral sides of abdomen more or less striped with black and mottled with red around black-striped area. Ventral postgenital spot large, reddish in the middle, black-bordered. White angular areas on abdomen more prominent than those described for male by Petrunkevitch (1939). Anterior spinnerets darker than in male, otherwise the same. About half way between anal tubercle and posterior abdominal humps an irregular dark spot consisting of five or six narrow cross bands observed in both sexes, but more evident in female. White patches of guanine dorsally, within region bounded by the four humps, as in male, and small spots of black and red also. Anterior humps tipped with black in female allotype, also faintly indicated in males in my collection. Legs all prominently ringed with reddish brown. These rings, although not mentioned in description of holotype male, found to be essentially the same in the two sexes, except often indistinct in male.

Epigynum. — Simple, with a fairly prominent, somewhat hairy lobule (Figs. 6–8).

Type locality. — Female allotype from Barro Colorado Island, Canal Zone, August, 1939. Female paratypes and males from same locality, June–August, 1934, 1936, 1939.

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THE GENUS *VESPULA* (HYMENOPTERA, VESPIDAE) IN MICHIGAN, WITH KEYS AND DISTRIBUTION

ROBERT R. DREISBACH

THE genus *Vespula* is a homogeneous, easily recognized group of wasps. Dr. Joseph Bequaert's paper on the hornets and yellow jackets of America (*Entomologica Americana*, N. S., 12[1931]: 71–138) makes another set of keys almost superfluous. However, since there are twenty species and varieties in that paper, whereas here only twelve are considered, the keys become somewhat simpler and easier to use.

The writer wishes to express his indebtedness to Dr. Bequaert for his determination and checking of species, and for his suggestions and criticism; and to Mr. F. M. Gaige, of the University of Michigan Museum, and Miss Eugenie McDaniels, of Michigan State College, who made available the specimens of this genus in the collections under their charge; also to Dr. Don Irish, of Midland, Michigan, through whose kindness the photomicrographs of the male genitalia were obtained.

The genus *Vespula*, family Vespidae, is a member of the superfamily Vespoidea of the aculeate Hymenoptera. The family Vespidae may be separated from the other families of the Vespoidea on the basis of the following characteristics:

Fore wings folded longitudinally in repose; antennae with 12 joints in female, 13 in male; first discoidal cell very long, generally much longer than submedian; transverse median vein in hind wing angulate; antennae not noticeably swollen apically; second cubital cell receiving both recurrent nervures.

Some of the terms used in the keys are:

Posterior orbits, that portion of the head just behind the compound eyes and bordering them from the base of the mandibles to the vertex.

Oculomalar space, the space between the lower front margin of the compound eyes and the base of the mandibles.

Tergite, the dorsal portion of an abdominal segment.

Sternite, the ventral portion of an abdominal segment.
Clypeus, the space from just below the insertion of the antennae to the front margin and extending laterally to the compound eyes.
Aedeagus, the male intromittent organ.

KEY TO THE SUBFAMILIES OF MICHIGAN VESPIDAE

1. Mandibles more or less elongate and knifelike, crossing each other or extended forward to form a beak, their inner margins toothed or notched; middle tibiae with one spur (very rarely with two or none); clypeus broadly rounded, truncate or emarginate at tip (very rarely pointed) Eumeninae
1. Mandibles short and broad, obliquely truncate and toothed at apex, folding above one another under clypeus or slightly crossing; middle tibiae with two spurs 2

2. Clypeus broadly truncate and more or less emarginate at apex; first abdominal tergite vertically truncate anteriorly; hind wing without an anal lobe, basal third strongly narrowed. (Hornets and yellow jackets) Vespinae
2. Clypeus pointed at apex, rarely rounded or straight; first abdominal tergite not vertically truncate and never narrowed into a stalk; hind wing with an anal lobe .... Polistinae

No attempt is made here to include the synonymy, as that has already been presented in the paper mentioned above. Eleven species and varieties of this genus have been taken in Michigan to date; since the related *Vespa crabro* L. will probably be collected in the state in the near future, it is included in the key.

KEY TO MICHIGAN VESPINAE

1. Head very large, with very wide (1.4–2.0 mm.) outer orbits; vertex long, about 1.4 mm. from posterior ocelli to posterior edge of vertex; sides of pronotum with a large vertical carina over entire upper edge .... *Vespa crabro* L.
1. Head small, with very much narrower outer orbits; posterior ocelli very close to posterior edge of vertex; vertex approximately 0.5 mm. long; ocelli about on a line with upper edge of eyes 2

2. Oculomalar space very short, approximately 0.2 mm. long, rarely more than one fifth length of antennal scape .... (subgenus *Vespula*) 3
2. Oculomalar space long, at least 0.5 mm., and approximately two fifths to two thirds length of antennal scape.... (subgenus *Dolichovespula*) 15

3. Two curved longitudinal yellow stripes on mesonotum, slightly shorter than mesonotum, reaching neither posterior nor anterior margin; abdomen of queen mostly orange, with anterior borders black; male and worker with abdomen mostly black, posterior margins of tergites with yellow bands .... *Vespula squamosa* (Drury)
3. No yellow stripes on mesonotum, which is entirely black............. 4

4. Queens and workers; antennae with 12 segments 5
4. Males; antennae with 13 segments 10

5. Posterior orbits with fine ridge on their posterior edges on upper half only; erect hairs on first abdominal tergite black 6
5. Posterior orbits with fine ridge on posterior edges over whole length, down to base of mandibles; ridge may be obscured for a short distance above mandibles, but this group, at least in Michigan, has erect hairs of first abdominal tergite always yellowish, not black; antennal scape black 9

6. Pale markings whitish .... *Vespula rufa* var. *consobrina* (Sauss)
6. Pale markings yellowish 7

7. Long erect hairs over whole length of upper side of hind tibiae; exposed part of sixth ventral abdominal segment as long as wide; third, fourth, and fifth ventral abdominal segments with large sparse punctures on posterior half, first half shining black, impunctate; no workers *Vespula austriaca* (Panzer)
7. No erect hairs over length of upper side of hind tibiae; exposed part of sixth ventral abdominal segment 1.4 broader than long in queen, slightly broader than long in workers; punctures on ventral abdominal segments smaller, surface dull, not shining 8

8. Second tergite without yellow spots; third, fourth, and fifth tergites mostly yellowish, enclosing black spots; second tergite with yellow band on posterior edge, narrow in middle and becoming broader toward sides; clypeus with three black elongate spots placed in triangle .... *Vespula rufa* var. *vidua* (Sauss)
8. Second tergite with yellow spots; postscutellum sometimes with yellow spots also; third, fourth, and fifth tergites mostly black; clypeus with broad black band, which may be anchor-shaped *Vespula rufa* var. *acadica* (Sladen)

9. First abdominal tergite black with posterior border yellow; abdomen with much more black than in following species, especially in queens; yellow posterior border of pronotum widened outwardly; black stripe connecting antennal sockets with vertex gradually broadened above; clypeus with black band in center; yellow band on outer orbits generally interrupted by a black spot at about center *Vespula vulgaris* (L.)
9. First abdominal tergite mostly yellow, with black triangle just in front of center and with anterior lateral corners black; yellow posterior border of pronotum narrow, not widened outwardly; black stripes connecting antennal sockets with vertex much narrowed above or entirely absent; clypeus with from one to three black spots, often almost entirely yellow; yellow band on outer orbits not interrupted with black .... *Vespula maculifrons* (R. du B.)

10. Disc of seventh abdominal tergite depressed and not evenly convex throughout; seventh abdominal sternite slightly notched at apex; aedeagus ending in an almost oval expansion 11
10. Disc of seventh abdominal tergite evenly convex throughout; seventh abdominal sternite evenly rounded and entire at apex; aedeagus shaft broad, ending in a saddle-shaped club 12

11\. Disc of seventh tergite abruptly depressed at basal third; apex very faintly if at all emarginate; black spot connecting antennal sockets with vertex much narrowed above or entirely absent; first abdominal tergite with a broader yellow band on posterior edge connected with a short yellow band each side of center on anterior edge, enclosing an oblong black spot which is open in front in center
Vespula maculifrons (R. du B.), Pl. I, Fig. 1

11\. Disc of seventh tergite sloping more gradually from base; apex with a very slight emargination; black stripe connecting antennal sockets with vertex gradually broadened above; first abdominal tergite with a narrow yellow band on posterior margin, anterior margin immaculate .... *Vespula vulgaris* (L.), Pl. I, Fig. 2

12\. Pale markings white .. *Vespula rufa* var. *consobrina* (Sauss), Pl. II, Fig. 1
12\. Pale markings yellow 13

13\. No yellow spots on second tergite; third, fourth, fifth, and sixth tergites mostly yellow, with the yellow enclosing black spots; anterior border of tergites in center, with a large V-shaped black spot; yellow band on posterior edge of pronotum broad
Vespula rufa var. *vidua* (Sauss), Pl. II, Fig. 2

13\. Two yellow spots on second tergite; third, fourth, fifth, and sixth tergites mostly black, with posterior edge bordered with narrow wavy yellow bands; band on posterior edge of pronotum very narrow 14

14\. Long erect hairs on upper edge of hind tibiae; a continuous yellow band on inner half of outer orbits; clypeus with narrow black band extending from center to anterior edge (yellow band on posterior orbits continuous) .... *Vespula austriaca* (Panzer).

14\. No erect hairs on upper edge of hind tibiae; yellow band on inner half of orbits interrupted in center by black spot; clypeus with a broad black band reaching from posterior to anterior edge
Vespula rufa var. *acadica* (Sladen)

15\. Markings white 16
15\. Markings yellow 17

16\. Lower sides of pronotum finely striate; long erect hairs on head, thorax, and first abdominal tergite yellowish to white; outer orbits much broader than in following species; longitudinal ridges on under side of segments of flagellum, beginning with third segment; first three abdominal tergites entirely black, the rest margined posteriorly with broad white indented bands ..... *Vespula maculata* (L.), Pl. III, Fig. 1

16\. Lower sides of pronotum smooth; long erect hairs on head, thorax, and first abdominal tergite black; no longitudinal ridges on under side of flagellum; first three abdominal tergites margined posteriorly with narrow bands of white, although band may be present only on sides of second tergite; rest of tergites margined with broader, indented, white bands; these bands narrower than in preceding species
Vespula adulterina var. *arctica* Roh., Pl. III, Fig. 2

17\. Yellow posterior border of pronotum continued downward on anterior edge, along vertical carina; yellow band on posterior orbits continu-

ous, though it may be narrowed in center; yellow band on first tergite with a V-shaped notch in center; branches of aedeagus broader, not tong-shaped, at apex .... *Vespula arenaria* (Fab.), Pl. IV, Fig. 1

17. Yellow posterior border of pronotum not continued downward along vertical carina; yellow band on posterior orbits interrupted in center with black; band on first tergite without notch; aedeagus more delicate, its branches at apex tong-shaped
Vespula norwegica var. *norvegicoides* (Sladen), Pl. IV, Fig. 2

The distributional records listed below are based on the collection in the University of Michigan, the collection of Michigan State College, the private collections of Mr. Curtis Sabrosky, Mr. George Steyskal, and the writer, and several smaller collections.

The need for further search for members of this group is shown by the fact that the species which has been found in the most localities, *Vespula arenaria* (Fab.), is known from only fifty-two counties in the state. Furthermore, no collections of *Vespula* have been made from the following twenty-one counties: Delta, Grand Traverse, Ogemaw, Mason, Muskegon, Kent, Tuscola, Ottowa, Ionia, Clinton, Shiawassee, St. Clair, Allegan, Barry, Eaton, Cass, St. Joseph, Branch, Hillsdale, Lenawee, Monroe. A great many other counties are represented by only one or two species. Cheboygan County, with eight species, has the largest number, followed by Mackinac with seven. There are four species known from Isle Royale, eight from the Upper Peninsula, and ten from the Lower Peninsula.

Vespula arenaria (Fab.), *V. maculifrons* (R. du B.), and *V. maculata* (L.) occur throughout the state and should be collected in every county. *V. adulterina* var. *arctica* Roh. has not been taken south of Clare County, but should be found in every county north of it. *V. norwegica* var. *norwegicoides* (Sladen) is a boreal species and has not been located south of Kalkaska County. Of the three varieties of *V. rufa*, var. *consobrina* (Sauss) seems to be the most northern, since it has been taken in practically all the counties of the Upper Peninsula and on Isle Royale. It is also common in the Lower Peninsula as far south as Huron County, and one collection each has been made in Livingston and Oakland counties. *V. rufa* var. *vidua* (Sauss) is not of frequent occurrence in the Upper Peninsula, but has been collected quite widely through the Lower Peninsula, and probably should be found in all the counties there. *V. rufa* var. *acadica* (Sladen) has been found only in Iosco and Kalkaska counties. *V. squamosa* (Drury) seems to reach about the

northern limit of its range in Washtenaw County, but should be present throughout the southern tier of counties.

Annotated List of Species and Varieties in Michigan

Vespula austriaca (Panzer). — According to Dr. Bequaert there are two specimens in the Museum of Comparative Zoölogy, Harvard University, labeled as from Michigan, but without the locality. One female, collected by Mr. A. W. Andrews in Chippewa County on July 10, 1913, is in the University of Michigan Museum.

Vespula maculifrons (R. du B.). — U. P.:[1] Dickinson, Alger, Chippewa. L. P.:[1] Cheboygan, Charlevoix, Leelanau, Oscoda, Alcona, Manistee, Roscommon, Lake, Clare, Gladwin, Arenac, Oceana, Mecosta, Isabella, Midland, Bay, Huron, Montcalm, Saginaw, Sanilac, Lapeer, Ingham, Livingston, Oakland, Macomb, Van Buren, Kalamazoo, Calhoun, Jackson, Washtenaw, Wayne, Berrien.

Vespula rufa var. acadica (Sladen). — Rare, the only records being from Kalkaska, collected July 8, by R. R. Dreisbach, and Iosco, collected July 16, by R. R. Dreisbach.

Vespula rufa var. consobrina (Sauss). — Isle Royale. U. P.: Keweenaw, Ontonagon, Baraga, Gogebic, Marquette, Alger, Dickinson, Schoolcraft, Luce, Chippewa, Menominee, Mackinac. L. P.: Emmett, Cheboygan, Charlevoix, Leelanau, Antrim, Benzie, Kalkaska, Crawford, Oscoda, Alcona, Midland, Bay, Huron, Livingston, Oakland.

Vespula rufa var. vidua (Sauss). — U. P.: Menominee, Mackinac. L. P.: Cheboygan, Otsego, Montmorency, Alpena, Grand Traverse, Kalkaska, Crawford, Alcona, Manistee, Wexford, Roscommon, Iosco, Lake, Osceola, Gladwin, Midland, Bay, Ingham, Livingston, Oakland, Washtenaw, Wayne.

Vespula squamosa (Drury). — Taken only twice in the state. One female was collected by Mr. Curtis Sabrosky in Van Buren County on June 23, 1938; another female, in the University of Michigan Museum, was taken on June 16, in Washtenaw County.

Vespula vulgaris (L.). — U. P.: Gogebic, Alger, Luce, Chippewa, Mackinac. L. P.: Cheboygan, Charlevoix, Kalkaska, Grand Traverse, Crawford.

[1] U. P., Upper Peninsula; L. P., Lower Peninsula.

Vespula adulterina var. arctica Roh. — U. P.: Baraga, Dickinson, Marquette, Luce, Chippewa, Menominee, Mackinac. L. P.: Cheboygan, Montmorency, Osceola, Clare.

Vespula arenaria (Fab.). — Isle Royale. U. P.: Houghton, Ontonagon, Baraga, Gogebic, Iron, Dickinson, Marquette, Alger, Schoolcraft, Chippewa, Menominee, Mackinac. L. P.: Emmett, Cheboygan, Presque Isle, Charlevoix, Leelanau, Antrim, Otsego, Montmorency, Benzie, Kalkaska, Crawford, Oscoda, Alcona, Manistee, Missaukee, Roscommon, Iosco, Lake, Osceola, Clare, Gladwin, Oceana, Newaygo, Mecosta, Isabella, Midland, Bay, Huron, Montcalm, Gratiot, Sanilac, Genesee, Lapeer, Ingham, Livingston, Oakland, Kalamazoo, Washtenaw, Wayne, Berrien.

Vespula maculata (L.). — Isle Royale. U. P.: Keweenaw, Houghton, Gogebic, Marquette, Schoolcraft, Luce, Chippewa, Mackinac. L. P.: Cheboygan, Leelanau, Otsego, Alpena, Benzie, Crawford, Oscoda, Manistee, Wexford, Missaukee, Iosco, Lake, Clare, Gladwin, Oceana, Newaygo, Isabella, Midland, Bay, Huron, Ingham, Livingston, Oakland, Kalamazoo, Washtenaw, Wayne, Berrien.

Vespula norwegica var. norvegicoides (Sladen). — Isle Royale. U. P.: Houghton, Dickinson, Mackinac. L. P.: Cheboygan, Kalkaska.

Midland, Michigan

PLATES I–IV

FIG. 1. *Vespula maculifrons* (R. du B.), male genitalia, ventral view

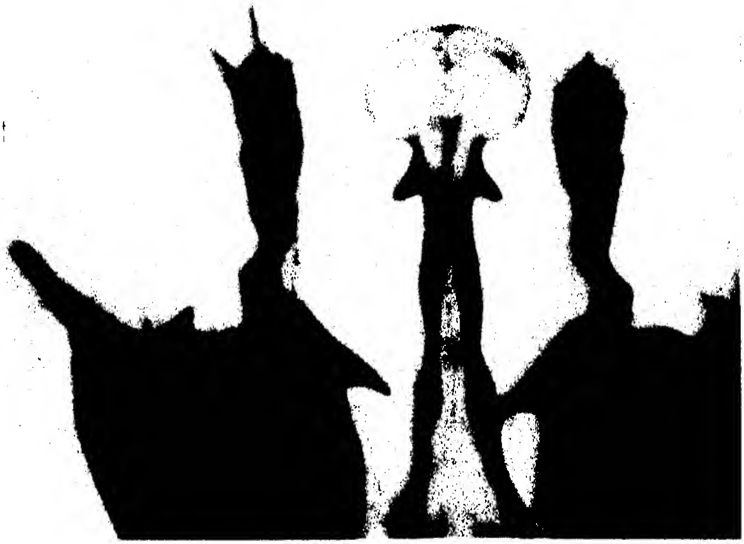

FIG. 2. *Vespula vulgaris* (L.), male genitalia, ventral view

FIG. 1. *Vespula rufa* var. *consobrina* (Sauss), male genitalia, ventral view

FIG. 2. *Vespula rufa* var. *vidua* (Sauss), male genitalia, ventral view

FIG. 1. *Vespula maculata* (L.), male genitalia, ventral view

FIG. 2. *Vespula adulterina* var. *arctica* Roh., male genitalia, ventral view

FIG. 1. *Vespula arenaria* (Fab.), male genitalia, ventral view

FIG. 2. *Vespula norwegica* var. *norvegicoides* (Sladen), male genitalia, ventral view

MATHEMATICAL RELATIONSHIP BETWEEN THE LENGTH AND THE AGE OF THE ROCK BASS, *AMBLOPLITES RUPESTRIS* (RAFINESQUE)

RALPH HILE

A NUMBER of species of fish, both marine and fresh-water, have been included among the animals employed for the investigation of the mathematical relationship between size and age. The equations derived have ranged in complexity from the relatively simple geometric-progression formulas developed by Ford (1933) for the marine herring and by Wagler for the northern pike (1936) and three species of coregonids (1937) to the rather complicated function applied by Pütter (1920) to the growth of Norwegian and Icelandic herrings. It does not come within the scope of this paper to undertake either a review of the various types of growth equations or a discussion of the logical and observational bases from which they were developed. Treatments of these subjects and numerous references to the literature may be found in publications by Pütter (1920), Ludwig (1929), von Bertalanffy (1934), Bückmann (1938), and others.

Directly pertinent to the subject of the present paper, however, is the growth formula derived by Weymouth and McMillin (1931) in connection with their investigation of the Pacific razor clam, *Siliqua patula*.[1] This equation, which was developed on the assumption, by no means new to biology, that the relative rate of growth decreases at a constant relative rate, took the form:

$$L = Be^{-ce^{-kt}},$$

where L = length,

t = time,

and B, c, and k = constants.

[1] Although the Weymouth and McMillin equation was not fitted to data on the growth of fish, a point in common between the methods employed for the

The curve, which is of the Gompertz type,[2] fitted the empirical data satisfactorily except in old age, when the empirical values were higher than the calculated values.

A possible objection to the equation of Weymouth and McMillin lies in the fact that it was developed from assumptions concerning the instantaneous rate of growth, although the empirical data provided information only on the length of the clams at one-year intervals. Obviously the course of growth of cold-blooded animals (with a winter slackening or cessation of growth) does not proceed along the smooth and continuous curve of the Weymouth-McMillin formula. Instead, the growth must be recognized as a periodic function whose values are defined only at unit intervals of time. Rigorous procedure would require that the assumptions from which the growth formula is developed be concerned only with size at intervals of one year and with increments of growth for one-year periods.

It is of some interest to learn what type of equation results when the basic assumption (namely, that the relative rate of growth decreases at a constant relative rate) is the same as that employed by Weymouth and McMillin, but when this relative growth is expressed only in terms of growth over finite (one-year) intervals of time.

If the relative rate of growth, $\phi(t)$, decreases at a constant relative rate we have the relationship:

$$\frac{\phi(t+1)}{\phi(t)} = B,$$

where $$B = \text{a constant } (O < B < 1). \tag{1}$$

It follows then that:

$$\phi(t) = CB^t. \tag{2}$$
$$C = \text{a constant.}$$

investigation of growth of certain mollusks and fish should be mentioned. Many species of both groups carry a history of past growth in the form of "winter rings" in the hard parts of the body (shells of mollusks; scales and bones of fish). A difference lies in the fact that the past growth of mollusks is measured directly on the shells, whereas the growth histories of fish are computed (by means of various formulas) from measurements of growth zones on scales or bones.

[2] See Winsor (1932) for a review of applications of the Gompertz curve to growth phenomena.

If size as a function of time is set as $f(t)$, we have by definition of the relative rate of growth:

$$\phi(t+1) = \frac{f(t+1) - f(t)}{f(t)} = CB^{t+1}. \tag{3}$$

From this relationship is obtained the final equation:

$$f(t) = K(CB+1)(CB^2+1)(CB^3+1) \cdots (CB^t+1). \tag{4}$$
K = a constant.

The final equation, which takes the form of a factorial, not only has an awkward appearance but presents the difficulty that the solution for $t = n$ requires the previous solution for all values of t less than n.

Considerable success was attained in fitting the equation to data on the growth of the 1923 year class of the rock bass, *Ambloplites rupestris*, of Nebish and Muskellunge lakes (Wisconsin). This year class was of such great abundance that large numbers could be taken at relatively advanced ages. Two circumstances contributed greatly to the reliability of the data as a true measure of the natural course of growth of rock bass in these lakes. The method of computing growth histories from scale measurements involved no large approximations, but was developed from a careful study of the actual relationship between body length and scale length. Furthermore, extensive data on the fluctuations (presumably from environmental causes) of growth rate in different calender years made possible the "correction" of the growth curves for the year class to eliminate distortion of the data from that source.

The data of Tables I and II on the growth of the 1923 year class of the Nebish Lake rock bass are based on 117 males and 99 females captured in 1931 during the ninth year of life and on 41 males and 74 females taken in 1932 during the tenth year of life. In the tables are presented: the average calculated lengths (second column) and increments of length (third column) as actually computed from scale measurements; the quality of growth in different years expressed as percentages of average or "normal" growth (fourth column); the calculated increments of length (fifth column) and calculated lengths (sixth column) after "correction" to eliminate the effects of annual fluctuations in growth rate; the empirical values of the relative growth rate, $\phi(t)$ (seventh column); and the values of the ratio,

TABLE I

GROWTH OF MALE NEBISH LAKE ROCK BASS OF THE 1923 YEAR CLASS

Standard lengths and annual increments of length as computed originally *from scale measurements and as corrected to eliminate the effects of fluctuations* in the quality of growth (given in table as percentages of average or "normal" growth) in different calendar years. At the right of the table are the empirical values of the relative growth rate, $\phi(t)$, and of $\phi(t+1)/\phi(t)$.

Year of life	Calculated length in millimeters	Increment of length	Quality of growth in calendar year of increment	"Corrected" increment	"Corrected" calculated length	$\phi(t)$	$\frac{\phi(t+1)}{\phi(t)}$
1	37.1	37.1	112.8	32.9	32.9	...	...
2	63.2	26.1	90.9	28.7	61.6	0.8723	...
3	93.2	30.0	95.6	31.4	93.0	0.5097	0.5843
4	120.2	27.0	95.1	28.4	121.4	0.3054	0.5992
5	140.0	19.8	91.9	21.5	142.9	0.1771	0.5799
6	152.6	12.6	84.8	14.9	157.8	0.1043	0.5889
7	163.7	11.1	98.1	11.3	169.1	0.0716	0.6865
8	171.8	8.1	108.4	7.5	176.5	0.0444	0.6201
9	180.0	8.2	120.6	6.8	183.4	0.0385	0.8671

$\frac{\phi(t+1)}{\phi(t)}$ (eighth column). The method of computing growth histories from scale measurements and the procedure for determining annual deviations from average growth have been described by Hile (1941).

In the data for the male rock bass, only the first four values of $\frac{\phi(t+1)}{\phi(t)}$ tended to fluctuate about a constant level; beyond the sixth year of life, therefore, the growth of the males failed to conform to the style of growth assumed for the derivation of equation (4). For this reason, only the data on growth during the first six years were employed in fitting the equation to the observed calculated lengths. The curve for the females also was fitted to the data for the first six years, although the values of $\frac{\phi(t+1)}{\phi(t)}$ in Table II prove the selection of this period to be to a certain extent arbitrary.

Table III contains comparisons of the original growth data of the 1923 year class of the Nebish Lake rock bass with lengths computed from equation (4). At the bottom of the table may be found the values of the constants B, C, and K. The equation fitted the

TABLE II

GROWTH OF FEMALE NEBISH LAKE ROCK BASS OF THE 1923 YEAR CLASS

Standard lengths and annual increments of length as computed originally from scale measurements and as corrected to eliminate the effects of fluctuations in the quality of growth (given in table as percentages of average or "normal" growth) in different calendar years. At the right of the table are the empirical values of the relative growth rate, $\phi(t)$, and of $\phi(t+1)/\phi(t)$.

Year of life	Calculated length in millimeters	Increment of length	Quality of growth in calendar year of increment	"Corrected" increment	"Corrected" calculated length	$\phi(t)$	$\frac{\phi(t+1)}{\phi(t)}$
1	36.0	36.0	112.8	31.9	31.9	...	...
2	62.6	26.6	90.9	29.3	61.2	0.9185	...
3	90.5	27.9	95.6	29.2	90.4	0.4771	0.5194
4	113.8	23.3	95.1	24.5	114.9	0.2710	0.5680
5	130.8	17.0	91.9	18.5	133.4	0.1610	0.5941
6	141.6	10.8	84.8	12.7	146.1	0.0952	0.5913
7	149.9	8.3	98.1	8.5	154.6	0.0582	0.6113
8	156.5	6.6	108.4	6.1	160.7	0.0395	0.6787
9	164.5	8.0	120.6	6.6	167.3	0.0411	1.0405

TABLE III

COMPARISON OF THE GROWTH (STANDARD LENGTH IN MILLIMETERS) OF THE 1923 YEAR CLASS OF THE NEBISH LAKE ROCK BASS AS COMPUTED FROM SCALE MEASUREMENTS AND AS CALCULATED BY MEANS OF EQUATION (4)

The values of the constants of the equation for fish of each sex are given.

Year of life	Males			Females		
	Length from scale measurements	Length from equation	Difference	Length from scale measurements	Length from equation	Difference
1	32.9	32.9	0.0	31.9	32.0	0.1
2	61.6	61.6	0.0	61.2	60.1	− 1.1
3	93.0	93.2	0.2	90.4	90.1	− 0.3
4	121.4	121.3	− 0.1	114.9	115.7	0.8
5	142.9	142.9	0.0	133.4	134.3	0.9
6	157.8	157.8	0.0	146.1	146.6	0.5
7	169.1	167.5	− 1.6	154.6	154.2	− 0.4
8	176.5	173.5	− 3.0	160.7	158.8	− 1.9
9	183.4	177.2	− 6.2	167.3	161.4	− 5.9
Values of constants	B		0.5881	B		0.5682
	C		2.5238	C		2.7187
	K		13.2350	K		12.5854

TABLE IV

GROWTH OF MALE MUSKELLUNGE LAKE ROCK BASS OF THE 1923 YEAR CLASS

Standard lengths and annual increments of length as computed originally from scale measurements and as corrected to eliminate the effects of fluctuations in the quality of growth (given in table as percentages of average or "normal" growth) in different calendar years. At the right of the table are the empirical values of the relative growth rate, $\phi(t)$, and of $\phi(t+1)/\phi(t)$.

Year of life	Calculated length in millimeters	Increment of length	Quality of growth in calendar year of increment	"Corrected" increment	"Corrected" calculated length	$\phi(t)$	$\frac{\phi(t+1)}{\phi(t)}$
1	33.8	33.8	104.9	32.2	32.2	...	...
2	50.8	17.0	102.0	16.7	48.9	0.5186	...
3	66.6	15.8	98.4	16.1	65.0	0.3292	0.6348
4	85.4	18.8	85.6	22.0	87.0	0.3385	1.0283
5	103.1	17.7	83.4	21.2	108.2	0.2437	0.7199
6	118.8	15.7	86.6	18.1	126.3	0.1673	0.6865
7	138.9	20.1	106.6	18.9	145.2	0.1496	0.8942
8	154.4	15.5	97.1	16.0	161.2	0.1102	0.7366
9	167.2	12.8	100.8	12.7	173.9	0.0788	0.7151

empirical data remarkably well over the first six years. The maximum deviations of the calculated lengths from the empirical values were 0.2 millimeter for the males and 1.1 millimeters for the females. The average deviations were 0.05 millimeter for the males and 0.62 millimeter for the females. The extrapolated portion of the curve, however, tended to fall below the empirical values. (The failure of growth formulas to describe growth late in life appears to be fairly common.)

The data of Tables IV, V, and VI on the 1923 year class of the Muskellunge Lake rock bass correspond exactly to the data given in Tables I, II, and III for the Nebish Lake rock bass. The numbers of fish on which the growth curves of the 1923 year class of the Muskellunge Lake rock bass were based were: 1930 — 18 males and 27 females in the eighth year of life; 1931 — 53 males and 68 females in the ninth year of life; and 1932 — 9 males and 10 females in the tenth year of life.

Although the values of $\frac{\phi(t+1)}{\phi(t)}$ varied more widely in the Muskellunge Lake rock bass than in the Nebish Lake rock bass, these variations were without detectable trend in the data for the Muskellunge

TABLE V

GROWTH OF FEMALE MUSKELLUNGE LAKE ROCK BASS OF THE 1923 YEAR CLASS

Standard lengths and annual increments of length as computed originally from scale measurements and as corrected to eliminate the effects of fluctuations in the quality of growth (given in table as percentages of average or "normal" growth) in different calendar years. At the right of the table are the empirical values of the relative growth rate, $\phi(t)$, and of $\phi(t+1)/\phi(t)$.

Year of life	Calculated length in milli-meters	Incre-ment of length	Quality of growth in calendar year of increment	"Corrected" increment	"Corrected" calculated length	$\phi(t)$	$\frac{\phi(t+1)}{\phi(t)}$
1	33.4	33.4	104.9	31.8	31.8	...	...
2	51.0	17.6	102.0	17.3	49.1	0.5440	...
3	66.3	15.3	98.4	15.5	64.6	0.3157	0.5803
4	83.3	17.0	85.6	19.9	84.5	0.3080	0.9756
5	98.7	15.4	83.4	18.5	103.0	0.2189	0.7107
6	112.1	13.4	86.6	15.5	118.5	0.1505	0.6875
7	131.0	18.9	106.6	17.7	136.2	0.1494	0.9927
8	144.4	13.4	97.1	13.8	150.0	0.1013	0.6780
9	153.8	9.4	100.8	9.3	159.3	0.0620	0.6120

TABLE VI

COMPARISON OF THE GROWTH (STANDARD LENGTH IN MILLIMETERS) OF THE MUSKELLUNGE LAKE ROCK BASS AS COMPUTED FROM SCALE MEASUREMENTS AND AS CALCULATED FROM EQUATION (4)

The values of the constants of the equation for fish of each sex are given.

Year of life	Males			Females		
	Length from scale measurements	Length from equation	Difference	Length from scale measurements	Length from equation	Difference
1	32.2	32.0	− 0.2	31.8	31.0	− 0.8
2	48.9	48.2	− 0.7	49.1	47.4	− 1.7
3	65.0	67.0	2.0	64.6	66.0	1.4
4	87.0	87.2	0.2	84.5	85.4	0.9
5	108.2	107.5	− 0.7	103.0	104.2	1.2
6	126.3	126.9	0.6	118.5	121.4	2.9
7	145.2	144.7	− 0.5	136.2	136.4	0.2
8	161.2	160.3	− 0.9	150.0	148.9	− 1.1
9	173.9	173.7	− 0.2	159.3	159.2	− 0.1
Values of constants	B 0.7736			B 0.7481		
	C 0.8423			C 0.9399		
	K 19.3985			K 18.2219		

Lake fish. In other words, the general style of growth of rock bass from Muskellunge Lake conformed approximately to that assumed originally throughout the nine years of life covered by the data, whereas in Nebish Lake the actual growth deviated notably from the theoretical beyond the sixth year of life.

The comparison of the theoretical lengths (equation based on data for all nine years of life) of Muskellunge Lake rock bass with the empirical calculated lengths reveals a reasonably good agreement. The average of the absolute values of the deviations was 0.67 millimeter for the males and 1.14 millimeters for the females. These average deviations were considerably larger than the corresponding deviations of 0.05 millimeter and 0.62 millimeter for the males and females of the Nebish Lake rock bass (first six years of life only).

The outstanding difference between the growth of the rock bass in Nebish Lake and that in Muskellunge Lake lies in the fact that in the former lake it deviated rather consistently from the theoretical curve beyond the sixth year, whereas in the latter the agreement between the lengths computed from the growth equation and the empirical lengths computed from scale measurements was fair throughout the nine years of life covered by the data. A possible explanation of this difference is suggested by the comparison of empirical and theoretical annual increments of length of rock bass of the two stocks (Table VII). In the Nebish Lake rock bass the empirical and theoretical increments of length agreed well during the first six years of life. It is true that in the data for the females differences as great as 1.2 and 1.1 millimeters occurred (second and fourth years of life, respectively). These maximum deviations were, however, of opposite signs and therefore most probably represent random errors. Beyond the sixth year of life the situation changed, for the empirical increments were consistently greater than the theoretical increments. The differences ranged from 1.5 to 3.1 millimeters in the males and from 0.9 to 4.0 millimeters in the females. In the Muskellunge Lake rock bass the differences between the empirical and the theoretical increments of length, although at times fairly large, apparently were distributed at random, that is, were not correlated with age.

The Nebish Lake data were characterized also by the extremely low values of the theoretical increments of length in the last three years of life (from 9.7 to 3.7 millimeters for the males and from 7.6

TABLE VII

Comparison of Increments of Length (in Millimeters) of Nebish Lake and Muskellunge Lake Rock Bass as Computed from Scale Measurements and as Computed from Equation (4)

Year of life	Nebish Lake				Muskellunge Lake			
	Males		Females		Males		Females	
	Computed from scale measurements	Computed from equation	Computed from scale measurements	Computed from equation	Computed from scale measurements	Computed from equation	Computed from scale measurements	Computed from equation
1	32.9	32.9	31.9	32.0	32.2	32.0	31.8	31.0
2	28.7	28.7	29.3	28.1	16.7	16.2	17.3	16.4
3	31.4	31.6	29.2	30.0	16.1	18.8	15.5	18.6
4	28.4	28.1	24.5	25.6	22.0	20.2	19.9	19.4
5	21.5	21.6	18.5	18.6	21.2	20.3	18.5	18.8
6	14.9	14.9	12.7	12.3	18.1	19.4	15.5	17.2
7	11.3	9.7	8.5	7.6	18.9	17.8	17.7	15.0
8	7.5	6.0	6.1	4.6	16.0	15.6	13.8	12.5
9	6.8	3.7	6.6	2.6	12.7	13.4	9.3	10.3

to 2.6 millimeters for the females). In Muskellunge Lake, however, the theoretical increments for these same years of life ranged from 17.8 to 13.4 millimeters for the males and from 15.0 to 10.3 millimeters for the females. It is suggested, therefore, that the failure of the growth of the Nebish Lake rock bass to follow the theoretical course during the later years of life may be ascribed to the exceptionally small theoretical increments of length during these years. With this explanation it is held that adherence beyond the sixth year of life to the style of growth that held during the first six years would involve a depression of the metabolic rate not compatible with the continued existence of the individual. In other words, the survival of the Nebish Lake rock bass to an advanced age may have been contingent upon a departure from the "normal" course of growth.

The extremely small theoretical length increments of the Nebish Lake rock bass in the later years of life may be traced to the rapid rate of decline of the relative rate of growth. The values of B (Table III) show that among the Nebish Lake males the ratio of the relative growth rate in a particular year of life to the relative growth

rate in the preceding year was on the average 0.5881 and that the corresponding ratio for the females averaged 0.5682 (both values based on growth in the first six years of life). The corresponding ratios for the Muskellunge Lake rock bass (based on growth throughout all nine years) were 0.7736 for the males and 0.7481 for the females (Table VI). The slower rate of decrease in the relative growth rate of the Muskellunge Lake fish accounted for the larger theoretical length increments in the later (sixth to ninth) years of life and may have made possible a survival to advanced ages without departure from the "normal" style of growth. It appears, then, that the rate of decrease of the relative growth rate may be of considerable biological significance.

I wish to thank Professor C. Eisenhart, of the University of Wisconsin, who read the manuscript critically.

SUMMARY

If it is assumed that the relative growth rate, as determined from annual increments of growth in length, decreases at a constant relative rate, the relationship between length (L) and age in years (t) may be expressed by the equation $L = K(CB + 1)(CB^2 + 1)(CB^3 + 1) \cdots (CB^t + 1)$, where K, C, and B are constants. This equation described accurately the growth of the 1923 year class of the rock bass from Nebish Lake (Wisconsin) during the first six years of life, but yielded values that were too low in the sixth to ninth years of life. The equation fitted reasonably well the data on growth of the 1923 year class of the rock bass from Muskellunge Lake (Wisconsin) over the nine years of life for which data were available. It was suggested that the theoretical increments of length (computed by means of the equation) of the Nebish Lake rock bass were so small that conformity in late years with the style of growth that prevailed during the first six years might well involve a depression of the metabolic rate not compatible with the continued existence of the individual. Thus in some populations survival to an advanced age may be contingent on a departure from the "normal" style of growth.

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MASS HYBRIDIZATION BETWEEN TWO GENERA OF CYPRINID FISHES IN THE MOHAVE DESERT, CALIFORNIA

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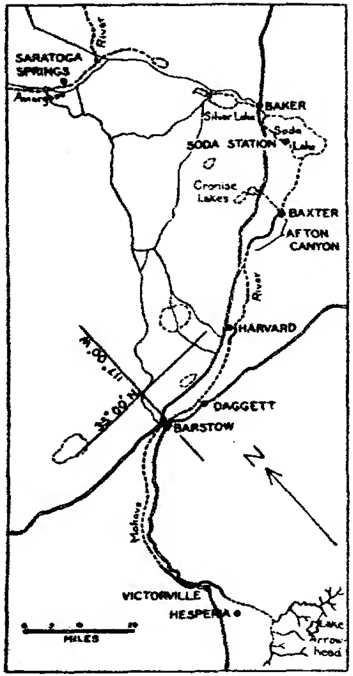
HYBRIDIZATION in nature between fish species is being analyzed by the senior author and his associates in a series of papers of which this is one. Each of these publications emphasizes a distinct point in the biological significance of natural hybridization. The present contribution [1] stresses the high frequency of interspecific hybridization that may result when a changed environment sets the stage for extensive miscegenation. To appreciate this relation between ecology and hybridization it is necessary to picture briefly the present and past hydrography of the Mohave River Basin.

HYDROGRAPHY OF THE MOHAVE DESERT

The Mohave Desert is properly included within the Great Basin, since all its permanent waters are characterized by interior drainage. The principal stream crossing this arid waste is the Mohave River (Fig. 1). Its headwaters (Fig. 2) rise high on the northern slopes of the San Bernardino Mountains of southern California, and it follows a generally northeasterly course for more than one hundred miles across the desert to "The Sink of the Mohave" (Soda Lake, a large discharging playa just south of the town of Baker). Within the river basin there are five major regions of perennial flow, where fishes may be found: (1) the headwater region, comprising fully 90 per cent of the total water supply and lying above the point where Deep Creek (the east fork) and West Fork unite (in high water) to

[1] In this study we have been materially aided by a research grant from the Horace H. Rackham School of Graduate Studies, of the University of Michigan. Sidney Shapiro, who served well as research assistant, made a considerable proportion of the counts and measurements. As usual, Laura C. Hubbs has borne the brunt of the statistical calculations. Professor Elliot Blackwelder, of Stanford University, kindly reviewed the geological discussion.



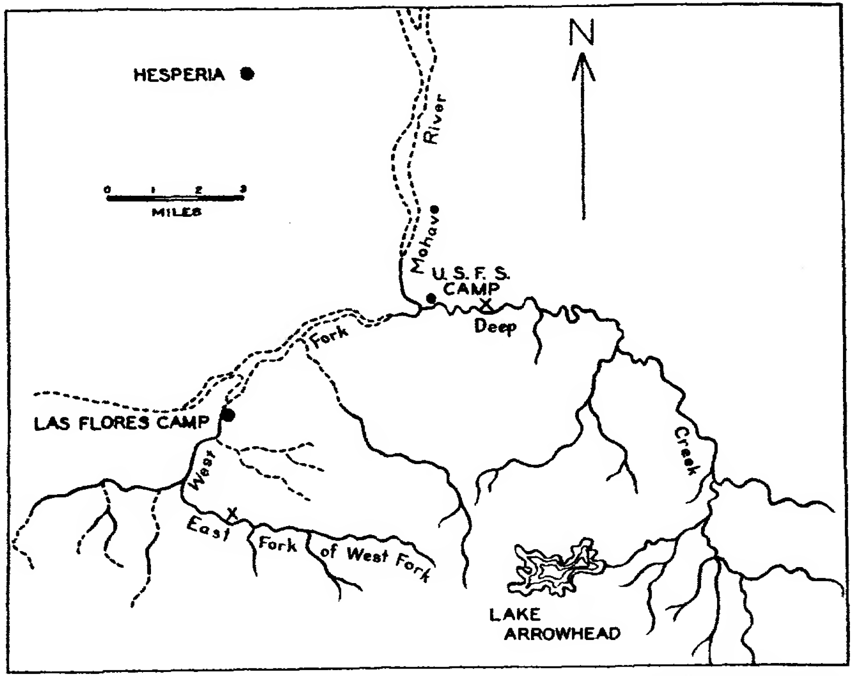


FIG. 1 (left). The present drainage features of the Mohave River system and vicinity. Perennial flows are indicated by solid lines; intermittent flows and the border of playas by dashed lines. Highways and dirt roads are also shown

FIG. 2. Detail of the headwater portion of the Mohave River system. X marks the uppermost points from which minnows have been obtained (Thomas Rodgers assisted in the drafting of both maps)

form the river proper; (2) the vicinity of Victorville, where there is a flow about seven miles in length; (3) a point south of Harvard (a railroad station about twenty miles east of Barstow), where there is a short flow; (4) Afton Canyon (about forty miles east of Barstow), where the river again flows six or seven miles; and (5) the west side of Soda Lake, at the railroad station of Soda, where a spring pool retains permanent water. Since this pond is higher than the adjacent playa bed, it is not subject to the effects of floodwaters, but all the other regions experience severe washouts from time to time.

Precipitation in the headwater region is relatively great, ranging from about 13 to 35 inches (Thompson, 1929 : 94). As a result, particularly in the Deep Creek basin, there are a considerable number of permanent and cool mountain creeks, but the stream mileage available to the native minnows is greatly restricted (Fig. 2). It is not certain to what extent the introduced trout rather than physical conditions limit the waters inhabited by minnows. As the river channel debouches from the base of the mountains onto the desert, a very rapid drop in rainfall occurs. Thus at Victorville, less than fifteen miles distant, the yearly fall is about five inches, and near Afton Canyon the precipitation is less than two inches (Thompson, 1929 : 80, 94). Consequently the occasional severe downpours in the mountainous region literally flush out the entire river (more particularly the lower portions), causing widespread change in the stream conditions and in the populations of aquatic organisms. Such a disastrous flood occurred in March, 1938, at which time the discharge not only filled Soda Lake but also overflowed into the playa of Silver Lake (the extreme flood terminus of Mohave River) just to the north. The effect of this washout on the native fishes is detailed in Table I.

The geological record clearly indicates that at some time during the Pleistocene, probably contemporaneously with lakes Lahontan and Bonneville, the waters of the Quaternary Mohave River formed a large body of water over the present playas of Silver and Soda lakes. This lake, the maximum area of which was about one hundred square miles, was named Lake Mohave by Thompson (1921 : 424). The level of its impounded waters eventually rose high enough to cut at the northern end a small outlet channel that served, for a time at least, to connect the Mohave River with the southeastern arm of Death Valley (Thompson, 1929 : 563–568). Here the stream joined the

Amargosa River, which flowed down from the north (Fig. 1). The conjoined waters contributed to the great lake (Lake Manly) which then existed in Death Valley.

Another body of water, considerably larger than Lake Mohave, is known to have covered the northeastern part of the flat valley east of Daggett. It has been called Manix Lake by Buwalda (1914 : 444). Recent studies of its deposits by Blackwelder and Ellsworth (1936) show that this lake had three stages, the first two correlated with two moist epochs during late Pleistocene time and the third possibly coincident with the close of the last ice advance. Whether it was strictly contemporaneous with Lake Mohave is not certain, but is highly probable, in the opinion of Blackwelder (personal communication).

A third Pleistocene lake, covering the present playas of East and West Cronise lakes, was formed by the Mohave River in Cronise Valley, about seventeen miles southwest of Baker (Fig. 1). Little Mohave Lake, as this body of water was named by Thompson (1921 : 424), was very much smaller than either Lake Mohave or Manix Lake, and appears to have had a very intermittent existence. Its eastern portion (East Cronise Lake) is still occasionally filled by distributary floodwaters from the Mohave River. The junior author saw minnows in that basin in 1937. According to local testimony the lake contained water from 1941 to the summer of 1942, when many fish perished as the lake dried up.

All these ancient lakes probably supported a dense population of the Mohave lake chub, *Siphateles mohavensis*, for, as is later pointed out, this species is particularly fitted for lacustrine conditions. Moreover, the record of fragmentary fish bones, identified as those of *Siphateles mohavensis*, from the first lake stage of Manix Lake (Blackwelder and Ellsworth, 1936 : 459), and another record by Buwalda (1914 : 449) of fish vertebrae (unidentified) from the same basin substantiate the presumed presence of *Siphateles* in such environments. With the disappearance of these bodies of water *Siphateles mohavensis* was largely forced to disperse into the headwater habitat of *Gila orcuttii*.

This study is one of several by which we are attempting to determine how the distribution and speciation of the fishes of the American desert have been affected by the profound hydrographic changes that occurred during and after Quaternary times (Hubbs, 1940b).

FISH FAUNA OF THE MOHAVE BASIN

With the exception of the disconnected springs and creeks of the Death Valley region, which harbor a limited fish fauna unrelated to that under consideration, as well as a few springs and short creeks that seem devoid of native fishes, all permanent waters of the Mohave Desert that have persisted into the present dry epoch are portions of the Mohave River system. These waters, now connected only in flood periods and at present probably never united into a single connected pattern, contain only two species of native fish (Pl. II). Both are members of the Cyprinidae and represent two genera that are widespread through the West. Except for brief indications by Miller (1938) and by Hubbs (1940b : 62), only one of the species, *Siphateles mohavensis* Snyder (1918), has been recorded from the basin. The second minnow seems to be inseparable specifically from *Gila* [2] *orcuttii* (Eigenmann and Eigenmann), which has hitherto been regarded as confined to the coastal streams of southern California. There are several hints that some catostomid fish occurred in the Mohave system until recently, but if it did, our extensive collecting from 1934 to 1940 indicates that it has been extirpated there.

Trout (*Salmo gairdnerii irideus*), introduced into the mountain headwaters, have probably restricted the numbers and range of the minnows. The several other exotic fishes recently added to the Mohave fauna have probably had as yet little effect on the native fish life.

Gila orcuttii and *Siphateles mohavensis* occur together, with hybrids, in nearly all parts of the generally disrupted Mohave River system (Fig. 1). The only place where the *Siphateles* appears to occur alone is in the spring pool on the ancient shore line of Quaternary Lake Mohave, of which the present southern remnant (Soda Lake) is the sump of the Mohave River. Regularly the *Gila* appears to ascend the streams farther than the *Siphateles* commonly goes, and shows more preference for the current. In the flowing streams the *Siphateles* tends to select the quieter pools.

That the *Gila* is better adapted than the *Siphateles* to stream life was dramatically proved in March, 1938, when a great flood raged

[2] The reference of this species to the genus *Gila* follows from the discovery that representatives of the nominal genera *Tigoma* and *Gila* merely represent ecological subspecies (Hubbs, 1940a : 200; 1941b : 186–187).

down the mountain sides and transformed the dry sands of the Mohave River bed into a torrent that filled the normal sump basin of Soda Lake and overflowed into the usually dry playa known as Silver Lake (Fig. 1). The force of the flood was so great that the stream beds were profoundly altered; for example, the lower end of the normal flow of Deep Creek was transformed from a large and beautiful pool (Pl. I, Fig. 4), five feet deep, into a sand-choked channel. The *Siphateles* population was swept out upon the desert in far greater proportion than was the stock of *Gila orcuttii*. As a result, the relative numbers of the two species were greatly altered. Comparing the samples of 1934 and 1937 with those taken in 1939 and 1940, we have estimated that the *Gila* population showed a relative increase of 66, 365, and 1,437 per cent in three portions of the stream system where the *Siphateles* stock decreased 89 to 93 per cent (Table I). *Siphateles* is estimated (p. 353) to have constituted 35 per cent of the Mohave minnow population in 1934 and 1937, but only 14 per cent of the total after the flood (from May, 1938, to August, 1940). That *Siphateles* was carried farther than *Gila* by the flood is indicated later (p. 355).

Siphateles mohavensis is obviously maladjusted to its present environment. Its survival may be accredited to lack of competition. There are only the two native fishes, and they are presumably complementary to a large degree in their food habits and other ecological relations.

These data on population ecology confirm the morphological evidence that had led us to regard *Gila orcuttii* as a fluviatile fish and *Siphateles mohavensis* as a lacustrine type. The *Gila* is the more streamlined: it has more turgid contours, is more terete (less slab-sided), and has a slenderer caudal peduncle (Pl. II). The *Gila* is darker and more mottled, like bottom-dwelling fishes in general; the *Siphateles* has a more uniform and more metallic color, approaching the appearance of pelagic fishes (see color descriptions, p. 372). The *Gila* has a more leathery integument and less fragile fin rays. The strong pharyngeal teeth of *Gila orcuttii* are adapted by their strong hooks and narrow grinding surfaces to a rapacious diet, presumably of stream insects; the weaker teeth of *Siphateles mohavensis*, with slight hooks and broad grinding surfaces (Pl. III), are fitted for the grinding of plankton, which is essentially a lake rather than a creek product. Correspondingly, the pharyngeal

TABLE I

RELATIVE NUMBERS OF *GILA ORCUTTII*, HYBRIDS, AND *SIPHATELES MOHAVENSIS* BEFORE AND AFTER THE GREAT FLOOD OF 1938

General locality and years	Numbers			Percentages		
	Gila	HYBRIDS	*Siphateles*	*Gila*	HYBRIDS	*Siphateles*
West Fork, Mohave River						
1934, 1937 (A) ...	22	16	78	19.0	13.8	67.2
1939, 1940 (B) ...	1,401	82	102	88.4	5.2	6.4
Change in percentage (B—A) ...	...	...	...	69.4	– 8.6	– 60.8
Hybrid index	...	...	...	...	60	...
Deep Creek						
1934, 1937 (A) ...	862	135	518	56.9	8.9	34.2
1939, 1940 (B) ...	317	10	8	94.6	3.0	2.4
Change in percentage (B—A) ...	...	...	...	37.7	– 5.9	– 31.8
Hybrid index	...	...	...	...	63	...
Mohave River near Victorville						
(1915)	...	...	(121)	...	...	(100.0)
1934, 1937 (A) ...	2	...	35	5.4	...	94.6
1939, 1940 (B) ...	332	28	40	83.0	7.0	10.0
Change in percentage (B—A) ...	...	...	...	77.6	?	– 84.6
Hybrid index	...	...	...	...	?	...

arches are stronger in *Gila* than in *Siphateles*. The long gill slits (Table XI) and numerous gillrakers (Table V) of the *Siphateles*, contrasting strongly with the similar characters of the *Gila*, are still more obvious adaptations to a plankton diet (Pl. IV). The characters of *Gila orcuttii* fit it for stream life; those of *Siphateles mohavensis* are adaptations to a lacustrine existence.

FREQUENCY OF HYBRIDIZATION

The interspecific hybridization discussed in this paper [3] was one of the two main cases that resulted in the following generalization (Hubbs, 1940b : 67): "Desiccation of waters has led to fusion as well as differentiation. Species which by their habits and by their feeding

[3] The hybridization between *Gila* and *Siphateles* was first mentioned by Miller (1938) and by Hubbs (1940b : 62).

TABLE II

RELATIVE NUMBERS OF *GILA ORCUTTII*, HYBRIDS, AND *SIPHATELES MOHAVENSIS* IN ALL AVAILABLE COLLECTIONS FROM THE MOHAVE RIVER BASIN

Locality (from headwaters to sump of Mohave River)	Numbers			Percentages		
	Gila	Hybrids	*Siphateles*	*Gila*	Hybrid	*Siphateles*
East Fork of West Fork of Mohave River, April 5, 1939	30	1	...	96.8	3.4	...
Same locality, Aug. 13, 1940	210	12	17	87.9	5.0	7.1
West Fork of Mohave River, Las Flores, June 29, 1937	5	4	20	17.2	13.8	69.0
Same locality, April 5, 1939	89	43	69	44.3	21.4	34.3
Same locality, July 11, 1940	176	19	12	85.0	9.2	5.8
Tributary to West Fork, Elliot Ranch, June 28, 1937	3	...	1	75(?)	...	25(?)
West Fork, Summit Valley, Aug. 31, 1934	7	4	45	12.5	7.1	80.4
Same locality, June 29, 1937	7	8	12	25.9	29.6	44.4
Same locality, July 12, 1940	518	2	3	99.0	0.4	0.6
West Fork just above Deep Creek, July 11, 1940	378	5	1	98.4	1.3	0.3
Deep Creek, about 1 mile above U. S. F. S. Camp, Sept. 27, 1931 *	...	1	2	...	33(?)	67(?)
Deep Creek at U. S. F. S. Camp, Sept. 1, 1934 (Pl. I, Fig. 4)	839	121	511	57.0	8.2	34.7
Same locality, June 30, 1937 *	23	14	7	52.3	31.8	15.9
Same locality, July 12, 1940	317	10	8	94.6	3.0	2.4
Mohave River about one fourth mile below Deep Creek, July 2, 1937	137	6	14	87.3	3.8	8.9
Mohave River about 5 miles below Deep Creek, April 5, 1939	17	...	...	100	...	...

* Sample taken with hook and line.

TABLE II (*Concluded*)

(Locality from headwaters to sump of Mohave River)	Numbers			Percentages		
	Gila	Hybrids	*Siphateles*	*Gila*	Hybrids	*Siphateles*
Floodwater pond, Mohave River, near Thorn, July 11, 1940	6	...	...	100	...	...
Spring tributary of Mohave River, near Victorville, Aug. 5, 1940	129	10	17	82.7	6.4	10.9
Mohave River, Victorville, Aug. 14, 1915	...	...	121	...	...	100
Same locality, Sept. 1, 1934	2	...	35	5.4	...	94.6
Same locality, April 8, 1939	91	18	22	69.5	13.7	16.8
Same locality, July 11, 1940	112	...	1	99.1	...	0.9
Mohave River, Daggett, March, April, May, 1903	...	...	9	...	...	100
Mohave River (stream), Afton Canyon, April 6, 1939	7	12	67	8.1	14.0	77.9
Same locality, July 26, 1940	212	63	65	62.4	18.5	19.1
Ponds in river, Afton Canyon, May 22, 1938	2	9	...	18.2	81.8	...
Same locality, April 7, 1939	6	37	122	3.6	22.4	74.0
Same locality, July 26, 1940	11	33	10	20.4	61.1	18.5
Isolated pond, Afton Canyon, April 6, 1939	16	10	13	41.0	25.6	33.3
Soda Lake spring, 1937–1940	...	...	608	...	...	100
Where species occur together (Soda Lake spring excepted)	3,350	442	1,204	67.2	8.9	24.0
1934 and 1937 (before 1938 flood)	1,023	157	645	56.1	8.6	35.3
1938 (after flood) – 1940	2,327	284	427	76.6	9.3	14.1
Grand total	3,350	442	1,812	59.9	7.9	32.2

apparatus and other structures are adapted respectively to lake life and to stream life, and which in periods of ample water no doubt had a complementary distribution, have hybridized *very extensively*

now that the two types have been forced into intimate contact in the isolated trickles and springs which represent the remnants of once expansive water systems."

The other case, that of the fluviatile *Siphateles obesus obesus* and the lacustrine *Siphateles obesus pectinifer*, of the Lahontan system, is almost exactly parallel in genetic as well as in historical and ecological respects. Almost the same difference in number of gill-rakers is involved. It is somewhat arbitrary that we regard the second case as one of subspecific intergradation rather than one of interspecific hybridization. Failing to recognize the numerous intermediates that occur where the two kinds meet, Snyder (1917: 60–67, figs. 4–6) treated *Siphateles obesus* and *Leucidius pectinifer* as even generically distinct. Furthermore, he described (pp. 58–59), on the basis of only four specimens from Lake Tahoe, a new species, *Richardsonius microdon*, which is obviously a hybrid between *Richardsonius egregius* and *Siphateles obesus*. This hybrid has many features in common with the one we are describing — particularly the intermediate character of dentition, gillrakers, and scales.

An abundance of material, taken in 1934 and 1937 (before the deluge of March, 1938), as well as after the flood, in 1938, 1939, and 1940, makes it possible for us to estimate the relative numbers of the parent species and the hybrids (Table II) in the Mohave basin. From the entire stream system we have random samples totaling 5,604 cyprinids,[4] of which the percentage composition is approximately:

Gila, 60; hybrids, 8; *Siphateles*, 32.

Exclusive of the *Siphateles* samples (608 specimens) from the Soda Lake spring, where this genus alone occurs, the percentages are about:

Gila, 67; hybrids, 9; *Siphateles*, 24.

The most significant single collection was that made in the lowest pool on Deep Creek (p. 348; Pl. I, Fig. 4), where the entire popula-

[4] Most of the material studied is in the fish collection of the University of Michigan Museum of Zoology. One collection in the Natural History Museum of Stanford University and one at Field Museum have also been studied, with the kind permission of the authorities of these institutions. The available collections, taken over several years, we judge to constitute between 1 and 10 per cent of the total standing population in the entire river system, at times when the surface waters are at a very low stage.

tion of 1,471 minnows was preserved on September 1, 1934. Here the percentages are as follows:

Gila, 57; hybrids, 8; *Siphateles*, 35.

The hybrid ratio for the whole basin was scarcely affected by the great flood of March, 1938:

Data for 1934 and 1937: *Gila*, 56.1 %; hybrids, 8.6 %; *Siphateles*, 35.3 %.
Data for 1938 (May) to 1940: *Gila*, 76.6 %; hybrids, 9.3 %; *Siphateles*, 14.1 %.

The flood of March, 1938, did cause some local changes in the hybrid ratio. The percentage of the hybrids in the population decreased in the headwater streams after 1938 (Table I). This loss was compensated for by the extremely high percentage of hybrids in the river and ponds in Afton Canyon from May, 1938, to August, 1940:[5]

Gila, 254 (37 per cent)
HYBRIDS, 164 (24 per cent)
Siphateles, 277 (40 per cent)

An average hybrid ratio of 8 or 9 per cent of the total population, increasing locally to at least 24 per cent, is indeed very exceptional, even in the Cyprinidae. Such a transgression of specific (and generic) lines involves a severe breakdown in the isolating mechanism. It would be expected, from observations as well as from theoretical considerations, that because of its biotic inefficiency such extensive hybridization between species would ordinarily be selected against. Interspecific hybrids are ordinarily infertile, in at least one sex, yet they compete for food and often for spawning sites. Some crosses endowed with hybrid vigor more than hold their own in such competition (as do the sunfishes — Hubbs and Hubbs, 1931–33).

Such a frequency of interspecific hybridization is rarely encountered, except where certain species, as *Salmo clarkii* and *Salmo gairdnerii*, are mixed by introductions. There is a possibility that the present case of hybridization is due to the introduction of *Gila orcuttii* from southern California, as a bait minnow, into the realm of *Siphateles mohavensis*. Only *Siphateles* is represented in the Mo-

[5] This canyon contained fish in 1936 (Miller, 1936), but neither pools nor fish in 1937 (Miller, 1938). The identification of the fish occurring in Afton Canyon in 1936 is uncertain, though the published tooth counts suggest that some hybrids as well as *Siphateles* were present.

have River collections of 1903 and 1915 — the only available series that were taken prior to 1931 (Table II). Slight differences between the specimens from the desert and those from the coastal streams, however, suggest that *Gila* is native to the Mohave River system.

We interpret the mass hybridization between *Gila orcuttii* and *Siphateles mohavensis* as having been made possible by reason of the very limited competition that exists between these species. They appear to be the only native fishes of the Mohave basin, and they are to a large degree complementary in their ecology (p. 347). In these desert waters the physical rather than the biotic environment seems to be the dominant factor in the struggle for existence.

EVIDENCE FOR HYBRID INTERPRETATION

The evidence that *Gila orcuttii* and *Siphateles mohavensis* hybridize in the Mohave River system is circumstantial rather than experimental, but nevertheless trustworthy, in our opinion. This type of evidence for natural hybridization has been discussed and, we think, validated in recent papers (Hubbs and Kuronuma, 1942; Hubbs, Hubbs, and Johnson, *in press*; Hubbs, Walker, and Johnson, *in press*). In these publications there is a detailed consideration of the character index, the hybrid index, and other analytical methods now being used in the interpretation of natural hybrids. In the present study the percentage *hybrid index* is computed on the basis of fixing the average values of the characters of the more primitive parental form, *Gila orcuttii*, as 0, and the values for *Siphateles mohavensis* as 100.

The theory that *Gila orcuttii* and *Siphateles mohavensis* hybridize extensively throughout most of the Mohave River system is thoroughly in line with the ecological picture. As noted on page 351, these species were probably complementary in habitat during the Pluvial period, but are now forced into cohabitation. The spring at Soda Lake is the only place in the whole system where the two species have not been taken together (Table II). They probably segregate to some degree ecologically, but they very commonly swim together.

The main reason for considering certain of the Mohave minnows hybrids is the intermediacy that they display in many respects. The *Gila* × *Siphateles* show an intermediate physiological characteristic, namely, the ability to withstand great floods. We have already pointed out that the populations of the stream type *Gila orcuttii* were proportionately much less decimated by the great flood of March,

1938, than were the headwater stocks of the lacustrine type *Siphateles mohavensis*. The changes in the relative numbers of the parental species and the hybrids in the two headwater branches of the Mohave River, namely, West Fork and Deep Creek, demonstrate clearly the intermediate capacity of the hybrids to resist the scouring wash (Table I). The hybrid indexes for the difference in the relative numbers of hybrids in the two headwaters before and after the flood are respectively 60 and 63 (an indication of a slightly greater resemblance to the *Siphateles* than to the *Gila*).

The extent to which the parental species and the hybrids were washed out on the desert by the 1938 flood also indicates the intermediacy of the hybrids. The *Gila* population was enormously increased in the upper portion of the Mohave River, from the junction of West Fork and Deep Creek, near the base of the mountains, out to the region of Victorville (Fig. 1; Tables I–II). As a rule, the hybrids were washed farther, for the hybrid ratio rose to 24 per cent of the total population in Afton Canyon (p. 353 and Table II). *Siphateles* was presumably largely carried still farther, out to the playa lakes (Soda and Silver). When these lakes dried up the fish doubtless perished in large numbers, as they did after the major flood of 1916, when they formed windrows of mummies (Thompson, 1929 : 566).

In the generic characters of pharyngeal teeth and gillrakers the hybrids display not only intermediacy, but also a degree of variability that would not be expected in a fixed species. Furthermore, their characteristics do not reasonably fit into the systematic pattern that is rather consistently displayed by Western fishes.

The pharyngeal-tooth formula of *Gila orcuttii* is almost consistently 2, 5—4, 2; that of *Siphateles mohavensis*, typically 0, 5—5, 0, and commonly 0, 5—4, 0; that of the hybrids, most commonly 1, 5—4, 1 (Table III; Pl. III). In forty counts of each unit only two rare variant formulae appear in the *Gila*, and only the one variation in the *Siphateles*, whereas eight variant formulae are displayed by 62.5 per cent of the hybrids counted. The number of teeth developed by the hybrids on the several rows is intermediate (Table IV). This is particularly true of the teeth in the outer (lesser) row: *Gila* almost always has 2 strong teeth in this row, on each arch: *Siphateles* has none; the hybrids have 0 to 2 (typically 1), usually weak teeth. This is contrary to the expected pattern, for the Western species of

TABLE III

FREQUENCIES OF PHARYNGEAL-TOOTH FORMULAE IN *GILA*, HYBRIDS, AND *SIPHATELES*

The frequencies of teeth in each series are given in Table IV; forty specimens of each kind were counted.

Kind	Formula *	Frequency
Gila orcuttii	2, 5—4, 2	36
	2, 5—4, 1	2
	2, 5—5, 2	2
HYBRIDS	1, 5—4, 1	15
	0, 5—4, 0	6
	1, 5—5, 1	5
	1, 5—4, 0	5
	1, 5—4, 2	3
	0, 5—4, 1	2
	0, 5—5, 0	2
	1, 5—5, 0	1
	2, 4—5, 2	1
Siphateles mohavensis	0, 5—5, 0	30
	0, 5—4, 0	10

* Frequently individual teeth are lost, and in the older fish often are not replaced. Almost always the loss can be accounted for by the presence of alveoli and by the spacing. Missing teeth were counted, of course. In a few hybrids and in one or two of the *Gila* specimens one tooth of the outer row may have been falsely enumerated, on the basis of what appeared to be a nearly filled-in alveolus.

Cyprinidae normally have either 0 or 2 teeth in this row. The presence of a single weak tooth in the outer row may be taken as a sign of hybridization — as it is for "*Richardsonius microdon*" (p. 352).

Hybridity is also indicated by other characters of the pharyngeal teeth and by the form of the arch (Pl. III). In *Gila orcuttii* the teeth, notably the lowermost one of the main row, are wider toward the base than those of *Siphateles mohavensis;* they are strongly instead of slightly hooked; they have narrow and weak, rather than broad and conspicuous, grinding surfaces. In the *Gila* the two limbs of the arch (as measured above the uppermost tooth and below the lowermost one) are subequal; in *Siphateles* the lower limb is definitely the longer. The lower limb near the teeth is narrow and rounded in the *Gila* (particularly in the adults), but is broad and flat in the Mohave *Siphateles.* The outer face of the arch bears a shelf for the insertion

TABLE IV

FREQUENCIES OF PHARYNGEAL-TOOTH COUNTS IN *GILA*, HYBRIDS, AND *SIPHATELES*

The formulae are given in Table III.

	Tooth counts								No.	Av.	Hybrid index
	0	1	2	3	4	5	9	10			
INNER (MAIN) ROW											
Left side											
Gila orcuttii	..	..	..	..	..	40	..	..	40	5.00	..
HYBRIDS	..	..	..	..	1	39	..	..	40	4.98	..
Siphateles mohavensis	..	..	..	..	..	40	..	..	40	5.00	..
Right side											
Gila orcuttii	..	..	..	..	38	2	..	..	40	4.05	..
HYBRIDS	..	..	..	..	31	9	..	..	40	4.23	33
Siphateles mohavensis	..	..	..	..	10	30	..	..	40	4.75	..
Both sides (sum)											
Gila orcuttii	..	..	..	..	..	..	38	2	40	9.05	..
HYBRIDS	..	..	..	..	..	..	32	8	40	9.20	21
Siphateles mohavensis	..	..	..	..	..	..	10	30	40	9.75	..
OUTER (LESSER) ROW											
Left side											
Gila orcuttii	..	..	40	..	..	..	..	..	40	2.00	..
HYBRIDS	10	29	1	..	..	..	..	..	40	0.77	61
Siphateles mohavensis	40	..	..	..	..	..	..	..	40	0.00	..
Right side											
Gila orcuttii	..	2	38	..	..	..	..	..	40	1.95	..
HYBRIDS	14	22	4	..	..	..	..	..	40	0.75	62
Siphateles mohavensis	40	..	..	..	..	..	..	..	40	0.00	..
Both sides (sum)											
Gila orcuttii	..	..	..	2	38	..	..	..	40	3.95	..
HYBRIDS	8	8	20	3	1	..	..	..	40	1.53	61
Siphateles mohavensis	40	..	..	..	..	..	..	..	40	0.00	..

of the two outer teeth in *Gila*, but in *Siphateles* has an even and steep slope, so that teeth could hardly find a base if they ever were present. In all these features of teeth and arch the hybrids are intermediate; or, commonly, they show a mixture of the features of the parental types. It seems that dental maladjustments occur in fish hybrids as well as in heterogeneous crosses in man and in dogs (Stockard and Johnson, 1941 : 367–383).

Similarly impressive variable intermediacy is exhibited by the characters of the gill arches (Pl. IV). In harmony with its presum-

TABLE V

FREQUENCIES OF GILLRAKER COUNTS IN *GILA ORCUTTII*, HYBRIDS, AND *SIPHATELES MOHAVENSIS*

Locality (see next page)	Kind	Number of gillrakers																							
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
A	*Gila*	..	9	22	10	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	...	...	2	3	10	13	5	1	2	2	..	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	..	3	3	6	7	11	10	9	3	3	2	..
B	*Gila*	5	16	63	27	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	...	...	2	3	16	32	41	16	2	2	..	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	2	2	2	1	5	20	21	25	20	8	4	..
C	*Gila*	5	28	77	39	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	...	...	..	1	3	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	..	2	..	..	..	3	3	2	2	1	1	..
D	*Gila*	1	15	19	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	...	...	..	..	3	11	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	2	2	3	7	4	2	1	..	1
E	*Gila*	2	9	38	21	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	2*	1*	11	11	7	15	7	2	4	5	1	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	..	..	1	3	8	10	21	13	7	3	..	..
F	*Siphateles*	..	..	...	...	..	..	..	..	..	..	..	..	..	..	1	4	6	17	19	20	9	2	2	..
A–F	*Gila*	13	77	219	102	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	HYBRIDS	..	..	2*	1*	15	18	39	71	56	22	8	9	1	..	..	..	..	..	..	..	..	..	..	..
	Siphateles	..	..	...	...	..	..	..	..	..	..	..	..	2	7	7	16	28	64	81	73	43	18	9	1

* Each count of 8 or 9 on one side of a hybrid is matched by a count of 11 on the other side; only a few specimens were counted on both sides.

TABLE V (*Concluded*)

STATISTICAL COMPUTATIONS

Locality	Kind	Range	No.	$M \pm \sigma_M$	Coefficient of variability (%)	Hybrid index
(A) West Fork of Mohave River	*Gila*	7–10	43	8.12 ± 0.15	9.65	..
	HYBRIDS	10–17	38	12.97 ± 0.26	12.44	32
	Siphateles	19–28	57	23.33 ± 0.28	9.13	..
(B) Deep Creek	*Gila*	6–10	123	8.20 ± 0.08	10.20	..
	HYBRIDS	10–17	114	13.52 ± 0.11	9.04	33
	Siphateles	18–28	110	24.38 ± 0.18	7.90	..
(C) Mohave River, ¼ to 5 miles below Deep Creek	*Gila*	6–10	154	8.07 ± 0.07	10.29	..
	HYBRIDS	11–15	6	12.67 ± 0.61	10.85	29
	Siphateles	19–28	14	24.00 ± 0.67	10.45	..
(D) Mohave River, Victorville	*Gila*	6–9	40	7.70 ± 0.11	9.28	..
	HYBRIDS	12–15	18	13.17 ± 0.20	6.33	33
	Siphateles	21–29	22	24.14 ± 0.39	7.63	..
(E) Mohave River, Afton Canyon	*Gila*	6–10	71	8.14 ± 0.09	9.29	..
	HYBRIDS	8–18	66	12.58 ± 0.29	18.57	28
	Siphateles	20–27	66	23.95 ± 0.19	6.35	..
(F) Soda Lake spring	*Siphateles*	20–28	80	24.09 ± 0.18	6.54	..
(A–F) All localities	*Gila*	6–10	431	8.09 ± 0.04	10.44	..
	HYBRIDS	8–18	242	13.13 ± 0.11	12.87	32
	Siphateles	18–29	349	24.03 ± 0.10	7.89	..

ably entomophagous habits, *Gila orcuttii* has the short gill slit and the few almost rudimentary gillrakers that are typical of the genus. In correlation with a probable plankton diet *Siphateles mohavensis* has deeply cleft gill slits and numerous slender functional gillrakers. In the hybrids the first gill slit is of almost exactly intermediate length (Table XI, second item); the values for the hybrid fill the gap between those for the parental species. The gillrakers number 6 to 10 in the *Gila*, 18 to 29 in the *Siphateles* (Table V). The values for the hybrids again fill the gap. Consistently through the river system the gillrakers average about 8 in the *Gila*, 13 in the hybrids, and 24 in the *Siphateles*. Only 19 of the 242 counts for the hybrids overlap the range of counts for both parental types. The coefficient of variability is about 10 per cent for the *Gila* and 8 per cent for the *Siphateles*, but definitely higher, 13 per cent, for the hybrids. A variation of 11 in the gillraker counts that average only 13 would be quite unexpected in any single form of fish that does not vary geographically in this respect. No explanation other than hybridization would be plausible.

Similar intermediacy is displayed by the scale structure (Pl. I, Figs. 1–3), which is strikingly different in *Gila orcuttii* and *Siphateles mohavensis*. The lateral scales of the *Gila* are typically much longer than high, have straightish upper and lower edges, and do not appear shield-shaped. Those of the *Siphateles* have more nearly equal axes and are strongly shield-shaped. The *Gila* scales have more radii, which extend onto the lateral (dorsal and ventral) fields and often occur on the basal field. The radii of the *Siphateles* are fewer, generally stronger, and more regular, and do not extend onto the lateral fields. In all these respects the hybrids cry out their intermediacy. Counts of radii for twenty adults of each form are given in Table VI.

The difference in the number of scales is not great, but the averages for all twelve enumerations (Table VII) are higher in the *Gila* than in the *Siphateles*. The averages for the hybrids are in general nicely intermediate, but with notable exceptions. The transverse counts tend to be high, and that from the origin of the dorsal fin to the lateral line is even higher than that in the *Gila*, giving a strange hybrid index of − 24. This aberrancy in the scale count is quite in agreement, however, with the fact that the measurement of the line along which this count was made, from the origin of the dorsal fin to the lateral line, averages definitely higher in the

TABLE VI

FREQUENCIES OF COUNTS OF SCALE RADII IN *GILA*, HYBRIDS, AND *SIPHATELES*

Based on adults used in Table XIII. Only those radii reaching the scale margin were counted. The scale selected was the one in the row next above the lateral line, directly over the insertion of the pelvic fin.

Kind	Number of scale radii									No.	Range	Av.	Hybrid index
	6–8	9–11	12–14	15–17	18–20	21–23	24–26	27–29	30–32				
Gila orcuttii ..	..	..	4	3	4	5	..	2	2	20	12–32	20.30	..
HYBRIDS	..	10	5	2	3	..	..	..	..	20	10–19	12.60	61
Siphateles mohavensis .	14	5	1	..	..	..	..	..	..	20	6–12	7.75	..

hybrids than in either parental species (Table XIII). This proportionately greater depth of the hybrids above the lateral line may well become established at the stage when the scales are formed there. It is a principle of lepidogenesis that more scales are laid down where there is greater space (Hubbs, 1941a).

The hybrids are interjacent in the number of fin rays, again with one significant exception. The sharpest differences lie in the number of pelvic rays, which typically number 8 in the *Gila*, 9 in the hybrids, and 10 in the *Siphateles* (Table VIII, first item). In the two large series counted the hybrid indices are 63 and 73, which indicates a somewhat greater similarity to the *Siphateles* than to the *Gila*.

Intermediacy, again with a somewhat greater approach toward the *Siphateles* parent, is shown by the hybrids in the number of anal rays (Table IX). The *Gila* typically has 7 anals; the *Siphateles*, 8. The hybrids usually have 8 rays in this fin, but 7 rays occur more frequently than in the *Siphateles*. The hybrid index of course is high, averaging 78. Correspondingly, the proportionate length of the anal base is about as great in the hybrids as in the *Siphateles* (Table XIII).

The dorsal rays show a slight but probably significant difference in average number in the parental species, with a hybrid index of 23 (Table X). The difference between the averages for the hybrids and those for the *Siphateles* is probably significant; but the averages for the hybrids and the *Gila* are not reliably different.

TABLE VII

SCALE COUNTS OF *GILA*, HYBRIDS, AND *SIPHATELES*

Based on twenty specimens of each category, all collected in lowest pool of Deep Creek, Mohave Desert, California, September 1, 1934.

Location of count	*Gila orcuttii*	HYBRIDS	*Siphateles mohavensis*	Hybrid index
Lateral line	52–63 (57.25)	49–58 (53.45)	44–55 (51.10)	62
Dorsal to lateral line	12–14 (13.20)	12–15 (13.55)	11–12 (11.75)	− 24
Anal to lateral line	8–10 (8.85)	8–9 (8.60)	7–9 (7.70)	22
Pelvic to lateral line	7–9 (7.90)	7–8 (7.55)	5–8 (6.90)	35
Predorsal scales	29–38 (34.15)	28–32 (30.20)	25–34 (28.25)	67
Predorsal rows	29–36 (32.75)	26–31 (28.60)	24–28 (26.35)	65
Around body				
above	26–29 (27.85)	25–29 (27.40)	23–27 (24.95)	16
below	23–27 (24.90)	22–27 (23.90)	20–24 (22.70)	45
total	53–58 (54.80)	49–58 (53.30)	45–52 (49.65)	29
Around peduncle				
above	14–16 (14.80)	13–16 (14.55)	12–15 (13.45)	19
below	13–15 (13.65)	12–15 (13.10)	11–14 (12.65)	55
total	29–33 (30.45)	28–32 (29.65)	25–31 (28.10)	34
			Average hybrid index	35

In the average number of pectoral rays (Table VIII) the hybrids exceed either parental species. The differences are small but almost certainly significant. The *t* values (ratios of the differences between the means to the standard error of the differences) are as follows:

Deep Creek collection:
Difference between hybrids and *Gila*, 1.29; standard error of this difference, 0.06; *t* value, 21.

Difference between hybrids and *Siphateles*, 0.36; standard error of this difference, 0.06; t value, 6.

Afton Canyon collection:

Difference between hybrids and *Gila*, 0.90; standard error of this difference, 0.9; t value, 10.

Difference between hybrids and *Siphateles*, 0.50; standard error of this difference, 0.8; t value, 6.

TABLE VIII

NUMBER OF PELVIC AND PECTORAL RAYS IN *GILA*, HYBRIDS, AND *SIPHATELES*

Collection and kind	Number of pelvic rays					No. of counts *	$M \pm \sigma_M$	Hybrid index
	7	8	9	10	11			
Deep Creek collection, September 1, 1934								
Gila orcuttii ...	4	174	22	..	..	200	8.09 ± .02	...
HYBRIDS	..	5	137	58	..	200	9.27 ± .04	73
Siphateles	..	4	50	146	..	200	9.71 ± .04	...
Afton Canyon collection, July 26, 1940								
Gila orcuttii ...	1	332	68	..	..	406	8.17 ± .02	...
HYBRIDS	..	9	96	21	..	126	9.10 ± .04	63
Siphateles	..	1	47	80	2	130	9.64 ± .05	...

Collection and kind	Number of pectoral rays							No. of counts *	$M \pm \sigma_M$	Hybrid index
	13	14	15	16	17	18	19			
Deep Creek collection, September, 1, 1934										
Gila orcuttii ...	1	26	113	58	2	..	..	200	15.17 ± .04	...
HYBRIDS	..	..	16	86	89	8	1	200	16.46 ± .05	139
Siphateles	..	..	33	120	42	5	..	200	16.10 ± .04	...
Afton Canyon collection, July 26, 1940										
Gila orcuttii ...	..	10	61	54	12	3	..	140	15.55 ± .07	...
HYBRIDS	..	1	9	51	59	4	..	124 †	16.45† ± .06	220
Siphateles	..	..	43	53	31	3	..	130	15.95 ± .06	...

* Both fins were separately enumerated.

† Not including one count of 0 rays (pectoral fin absent on one side of one fish).

TABLE IX

NUMBER OF ANAL RAYS IN *GILA*, HYBRIDS, AND *SIPHATELES*

Collection and kind	Number of anal rays					No. of speci-mens	Av.	Hybrid index
	6	7	8	9	10			
West Fork of Mohave River								
Gila orcuttii	..	124	2	..	..	126	7.02	..
HYBRIDS	..	14	38	..	..	52	7.73	75
Siphateles mohavensis	..	1	80	..	..	81	7.99	..
Deep Creek								
Gila orcuttii	3	115	5	..	..	123	7.02	..
HYBRIDS	..	22	91	1	..	114	7.82	84
Siphateles mohavensis	..	3	101	3	..	107	8.00	..
Mohave River, ¼ to 5 miles below Deep Creek								
Gila orcuttii	..	152	2	..	..	154	7.01	..
HYBRIDS	..	3	3	..	..	6	7.50	51
Siphateles mohavensis	..	1	12	1	..	14	8.00	..
Mohave River, Victorville								
Gila orcuttii	1	90	1	..	..	92	7.00	..
HYBRIDS	..	3	15	..	..	18	7.83	86
Siphateles mohavensis	..	2	55	..	..	57	7.96	..
Mohave River, Afton Canyon								
Gila orcuttii........	4	87	6	..	..	97	7.02	..
HYBRIDS	1	34	67	4	1	107	7.72	79
Siphateles mohavensis	1	13	176	1	..	191	7.93	..
Soda Lake spring								
Siphateles mohavensis	..	1	75	4	..	80	8.04	..
All localities								
Gila orcuttii	8	568	16	..	..	592	7.01 *	..
HYBRIDS	1	76	214	5	1	297	7.76 †	78
Siphateles mohavensis	1	21	499	9	..	530	7.97 §	..

* Standard error, 0.01.
† Standard error, 0.03.
§ Standard error, 0.01.

This is a most unexpected result, but the increased pectoral-ray count in the hybrid harmonizes with the fact that the pectoral fin in the hybrids is larger than in either parental species, just as the

TABLE X

NUMBER OF DORSAL RAYS IN *GILA*, HYBRIDS, AND *SIPHATELES*

Collection and kind	Number of dorsal rays				No. of specimens	Av.
	7	8	9	10		
West Fork of Mohave River						
Gila orcuttii	3	122	1	..	126	7.98
HYBRIDS	1	43	8	..	52	8.13
Siphateles mohavensis	..	69	11	1	81	8.16
Deep Creek						
Gila orcuttii	3	119	1	..	123	7.98
HYBRIDS	21	89	4	..	114	7.85
Siphateles mohavensis	1	97	9	..	107	8.07
Mohave River, ½ to 5 miles below Deep Creek						
Gila orcuttii	1	151	2	..	154	8.01
HYBRIDS	..	5	1	..	6	8.17
Siphateles mohavensis	..	11	3	..	14	8.21
Mohave River, Victorville						
Gila orcuttii	4	84	3	..	91	7.99
HYBRIDS	..	18	..	..	18	8.00
Siphateles mohavensis	..	22	..	..	22	8.00
Mohave River, Afton Canyon						
Gila orcuttii	2	65	3	..	70	8.01
HYBRIDS	..	48	15	..	63	8.24
Siphateles mohavensis	..	52	13	..	65	8.20
Soda Lake spring						
Siphateles mohavensis	..	73	7	..	80	8.09
All localities						
Gila orcuttii	13	541	10	..	564	7.99 *
HYBRIDS	22	203	28	..	253	8.02 †
Siphateles mohavensis	1	324	43	1	369	8.12 §

* Standard error, 0.01.
† Standard error, 0.03; hybrid index, 23.
§ Standard error, 0.02.

higher count of scales between the dorsal fin and the lateral line in the hybrids is consistent with the greater depth of the body in the same region. Something in the constitution of the hybrids seems to have been responsible for a better-developed pectoral fin.

The fins of the hybrids show intermediacy in a very interesting structural feature. The appendages of the *Gila* are very tough and

TABLE XI

FREQUENCIES OF BODY-PROPORTION RATIOS IN *GILA*, HYBRIDS, AND *SIPHATELES*

Based on the data used for Table XIII.

100 × standard length / Dorsal to occiput	31	32	33	34	35	36	37	38	39	40	41	No.	Av.	Hybrid index
Males														
Gila orcuttii	..	..	..	1	2	4	1	..	2	..	..	10	36.3	..
HYBRIDS	..	1	1	5	2	1	..	..	..	..	..	10	34.2	62
Siphateles mohavensis	1	2	5	2	..	..	..	..	..	..	..	10	32.9	..
Females														
Gila orcuttii	..	..	..	..	1	..	..	3	5	..	1	10	38.3	..
HYBRIDS	..	..	..	1	1	3	4	..	1	..	..	10	36.3	62.5
Siphateles mohavensis	..	..	..	3	3	4	..	..	..	..	..	10	35.1	..
1000 × standard length / First gill-slit length		67–70	71–74	75–78	79–82	83–86	87–90	91–94	95–98	99–102	103–106	No.	Av.	Hybrid index
Gila orcuttii		11	4	5	..	..	..	..	..	..	..	20	72	..
HYBRIDS		..	..	..	4	9	3	3	1	..	..	20	86	58
Siphateles mohavensis		..	..	..	..	..	2	5	3	9	1	20	97	..
Eye to preopercle / Internarial width		0.75–0.80	0.81–0.86	0.87–0.92	0.93–0.98	0.99–1.04	1.05–1.10	1.11–1.16	1.17–1.22	1.23–1.28	1.29–1.34	No.	Av.	Hybrid index
Gila orcuttii		2	3	7	4	3	1	..	..	..	..	20	0.915	..
HYBRIDS		..	..	..	2	8	6	1	2	1	..	20	1.06	55
Siphateles mohavensis		..	..	..	..	..	4	3	9	1	3	20	1.18	..
Dorsal height / Anal height	1.07–1.09	1.10–1.12	1.13–1.15	1.16–1.18	1.19–1.21	1.22–1.24	1.25–1.27	1.28–1.30	1.31–1.33	1.34–1.36	1.37–1.39	No.	Av.	Hybrid index
Gila orcuttii	2	4	7	6	1	..	..	..	..	..	..	20	1.14	..
HYBRIDS	..	..	1	2	5	8	2	2	..	..	..	20	1.22	50
Siphateles mohavensis	..	..	..	1	..	..	3	6	3	3	2	18	1.30	..

leathery, perhaps in correlation with its life in rapid water, and the fin rays are very strong. The fins of the *Siphateles* have the skin and rays thinner and more fragile. In single collections that were preserved and handled together the caudal fins are intact in nearly all the *Gila* specimens, but are broken in a considerable proportion of the hybrids and in almost all the *Siphateles* specimens. There is a similar difference between the parental species in the thickness and leatheriness of the skin over the body, and in this respect, too, the hybrids are intermediate.

The hybrids are interjacent between the parental species in the relative height of the dorsal and anal fins (Table XI, last item). On the average the *Gila* has the dorsal fin lower but the anal fin higher than they are in the *Siphateles* (Table XIII). The differences, consequently, are emphasized by comparing the ratios between the dorsal height and the anal height. In this ratio the interspecific crosses are exactly intermediate, showing a hybrid index of 50.

The hybrids are also intermediate in the average position of the dorsal fin. This is indicated by the measurements of the predorsal length and of the distance from the dorsal fin to the occiput, when these are expressed in thousandths of the standard length (Table XIII). When the sexes are treated separately and the discordant length of the head is eliminated, the parental species are seen to overlap but little, and the hybrid indices are about 62.

The relatively high dorsal fin and short predorsal space in the *Siphateles* calls for a comparison of the parental species and the hybrids in the ratio between these two values (Table XII). In the smaller fish the hybrids are definitely intermediate in this ratio (the hybrid index is 62). In the adults the dorsal fin of the hybrids decreases less in relative length than it does in either parental species. As a result, it becomes about as long proportionately as in the *Siphateles* (Table XIII). The hybrid index for the quotient, dorsal height to dorsal–occiput interspace, is about 85 in the adult (Table XII).

The other proportionate measurements of the fins (Table XIII, last 6 items) almost equal or even exceed the values for the *Siphateles* (or, in the anal height only, the value for the *Gila*). The constitution of the hybrids apparently causes them to have large fins.

Another ratio emphasizes observed differences between the parental species and the intermediate position of the hybrids. In the

TABLE XII

FREQUENCIES OF PROPORTIONS, DISTANCE FROM ORIGIN OF DORSAL FIN TO OCCIPUT DIVIDED BY DORSAL HEIGHT, IN SPECIMENS OF *GILA*, HYBRIDS, AND *SIPHATELES*

Collection, standard length, and kind	Dorsal fin to occiput / Dorsal height												No.	Av.	Hybrid index
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1			
West Fork of Mohave River, April 5, 1939; 44 to 85 mm.															
Gila orcuttii	..	..	..	..	..	1	5	3	2	3	2	..	16	1.74	..
HYBRIDS	..	..	1	4	2	3	2	1	..	..	..	..	13	1.43	84
Siphateles mohavensis	..	..	3	6	5	2	2	..	..	..	..	..	18	1.37	..
Deep Creek, September 1, 1934; 51 to 92 mm.															
Gila orcuttii	..	..	..	..	..	1	4	2	5	5	2	1	20	1.79	..
HYBRIDS	..	..	..	..	4	7	2	6	1	..	..	..	20	1.56	85
Siphateles mohavensis	..	..	..	..	8	3	5	2	1	..	..	..	19	1.52	..
Deep Creek, September 1, 1934; 23 to 31 mm.															
Gila orcuttii	..	..	1	7	14	7	1	..	..	..	..	..	30	1.40	..
HYBRIDS	..	3	12	13	2	..	..	..	..	..	..	..	30	1.25	62
Siphateles mohavensis	3	10	12	5	..	..	..	..	..	..	..	..	30	1.16	..

TABLE XIII

PROPORTIONATE MEASUREMENTS OF ADULTS OF *GILA*, HYBRIDS, AND *SIPHATELES*

Expressed in thousandths of the standard length. Each item (range, with mean in parenthesis) derived from ten measurements, except as indicated by subscript numbers. Based on a single large collection made in Deep Creek, Mohave Desert, California, September 1, 1934.

	Males			Females		
	Gila orcuttii	HYBRIDS	*Siphateles mohavensis*	*Gila orcuttii*	HYBRIDS	*Siphateles mohavensis*
Standard length, mm.	51.3–62.1 (57.1)	55.2–72.5 (63.0)	52.1–70.3 (61.6)	55.5–80.8 (67.2)	55.2–87.3 (66.9)	56.0–91.6 (72.5)
Predorsal length	555–592 (570)	531–573 (557)	531–556 (545)	551–615 (585)	567–598 (579)	549–582 (565)
Dorsal to occiput	343–390 (363)	323–359 (342)	315–342 (329)	353–408 (383)	343–386 (363)	336–363 (351)
Prepelvic length	533–562 (550)	536–579 (558)	525–568 (549)	537–565 (551)	554–578 (566)	545–563 (552)
Anal origin to caudal base ..	292–333 (313)	296–317 (307)	292–318 (303)	279–303 (291)	275–308 (292)	277–295 (286)
Caudal peduncle, length	193–225 (213)	185–224 (200)	194–223 (200)	191–212 (203)	184–214 (199)	181–200 (191)
Caudal peduncle, depth	121–142 (132)	130–141 (135)	126–138 (132)	119–131 (124)	123–140 (131)	123–138 (131)
Lateral line to dorsal origin .	156–180 (167)	162–182 (175)	156–179 (165)	143–164 (155)	155–181 (167)	147–168 (161)
Lateral line to pelvic insertion	99–111 (105)	90–119 (101)	86–114 (100)	95–117 (105)	98–108 (103)	82–126 (105)
Body depth	270–297 (286)	266–312 (288)	254–298 (277)	259–300 (278)	276–317 (292)	268–306 (281)
Head length ...	279–302 (288)	293–315 (306)	283–310 (301)	276–305 (290)	302–325 (313)	287–318 (307)
Head depth	204–221 (210)	196–215 (208)	193–216 (204)	198–217 (205)	202–224 (211)	198–214 (205)
Head width	155–169 (162)	149–174 (158)	147–168 (155)	149–176 (163)	156–188 (167)	148–170 (159)
Interorbital width	86–101 (96)	91–100 (96)	85–99 (92)	90–101 (96)	98–111 (103)	90–104 (94)
Internarial width	49–62 (55)	48–59 (53)	45–53 (49)	49–61 (53)	52–61 (58)	45–54 (50)
Suborbital width	31–39 (35)	31–42 (35)	34–40 (37)	35–39 (37)	35–46 (38)	32–42 (37)
Snout length ...	73–87 (79)	75–90 (82)	70–82 (74)	78–88 (82)	79–93 (87)	69–91 (78)
Eye length	61–65 (63)	60–72 (67)	64–73 (68)	54–65 (59)	57–69 (65)	58–69 (65)

TABLE XIII (*Concluded*)

	Males			Females		
	Gila orcuttii	Hybrids	*Siphateles mohavensis*	*Gila orcuttii*	Hybrids	*Siphateles mohavensis*
Eye to preopercle	43–53 (48)	53–61 (57)	51–62 (57)	47–56 (50)	55–65 (61)	53–66 (60)
Opercle length .	92–113 (101)	99–107 (104)	96–117 (105)	93–109 (100)	94–114 (106)	101–115 (107)
Upper jaw length	76–87 (81)	77–93 (86)	71–80 (77)	76–98 (85)	85–96 (92)	74–87 (80)
Mandible length	101–112 (107)	100–117 (109)	102–109 (106)	102–116 (108)	107–119 (115)	103–115 (108)
First gill-slit length	68–78 (72)	81–93 (86)	88–101 (97)	68–77 (72)	80–96 (87)	89–105 (97)
Dorsal height ..	208–244 (219)	218–244 (233)	227–239 (234)	183–209 (200)	207–236 (221)	201–226 (215)$_{9}$
Dorsal base	106–135 (119)	118–140 (129)	114–128 (122)	105–121 (109)	111–130 (119)	111–127 (121)
Anal height	179–208 (193)	175–201 (191)	167–184 (178)$_{9}$	164–185 (175)	166–202 (181)	156–177 (166)
Anal base	90–104 (96)	97–114 (103)	91–107 (99)	76–89 (84)	79–102 (93)	85–105 (93)
Caudal, longest ray, lower lobe	228–270 (243)$_{8}$	256–289 (272)$_{3}$	257–290 (279)$_{4}$	208–254 (235)$_{8}$	245–291 (270)$_{3}$	....
Pectoral length .	193–225 (210)	214–241 (228)	217–238 (224)	172–189 (182)	195–217 (198)	183–195 (188)
Pelvic length ...	157–188 (167)	169–197 (183)	173–193 (180)	129–153 (144)	157–183 (164)	156–176 (166)

Gila, as compared with the *Siphateles*, the internarial width (the least distance between the anterior nostrils) is relatively large, but the distance from the eye to the preopercle is relatively small (Table XIII). The ratio between the two proportions (Table XI, third item) shows almost no overlap. The values for the hybrids range between the means for the parental species. The hybrid index of 55 is only 10 per cent above one of exact intermediacy.

Other measurements of the hybrids do not conform with the general rule, that the characters of interspecific fish hybrids are intermediate and unlike those of either parental species. Reviewing the figures in Table XIII, we note that the measurements of the hybrids (expressed in thousandths of the standard length) are high and often extreme for the depth of the head, body, and caudal peduncle, for the length of the head and the parts thereof, and, as already noted,

TABLE XIV

PROPORTIONATE MEASUREMENTS OF HEAD PARTS IN ADULTS OF *GILA*, HYBRIDS, AND *SIPHATELES*

Expressed in thousandths of head length. Each item (range, and mean in parenthesis) derived from twenty measurements. Based on data used in Table XIII.

Head part	*Gila orcuttii*	HYBRIDS	*Siphateles mohavensis*	Hybrid index
Head depth	655–772 (719)	650–715 (675)	626–724 (673)	96
Head width	529–602 (562)	479–602 (525)	484–565 (517)	82
Interorbital width	306–352 (331)	301–353 (321)	282–328 (311)	50
Internarial width	168–213 (187)	156–198 (180)	151–172 (163)	29
Suborbital width	109–136 (124)	100–144 (118)	109–133 (121)	200 ?
Snout length	253–301 (279)	251–298 (272)	232–287 (251)	25
Eye length	187–228 (211)	179–238 (214)	184–241 (219)	37.5
Eye to preopercle	154–186 (171)	173–204 (190)	172–208 (192)	90
Opercle length	318–381 (349)	310–366 (338)	323–380 (349)	...
Upper jaw length	268–299 (284)	247–319 (288)	231–274 (259)	− 16
Mandible length	350–390 (370)	338–390 (363)	338–364 (354)	44
First gill-slit length	233–271 (249)	245–307 (279)	283–339 (319)	43
Average hybrid index (opercle measurement excluded)				62

for the length of the fins. The high values for the measurements of the head parts, as expressed in relation to the standard length, are due chiefly to the large size of the head, for when the measurements of the head parts are given in thousandths of the head length (Table XIV) intermediacy is generally indicated.

Life colors (noted in the field on September 1, 1934, when the large collection was secured in Deep Creek) give the hybrids an obvious intermediate appearance:

GENERAL TONE:
- *Gila:* darker
- HYBRIDS: variably intermediate
- *Siphateles:* lighter

UPPER PARTS:
- *Gila:* blotched with olive-blackish and olive-brassy colors
- HYBRIDS: variably intermediate
- *Siphateles:* relatively uniform, dark olive

LOWER SIDES:
- *Gila:* silvery, with more gold than in the *Siphateles*, but also with blue reflections; punctulate with olive black
- HYBRIDS: with a mixture of the gold of the *Gila* and the blue of the *Siphateles*
- *Siphateles:* bluish white, with brilliant blue and gold reflections, the blue predominating

LOWER SURFACE:
- *Gila:* blue white anteriorly; creamy posteriorly
- HYBRIDS: (not specified)
- *Siphateles:* bluish white; scarcely cream-colored posteriorly

SIDES OF HEAD:
- *Gila:* with brilliant gold reflections, brightest in a bar just behind preopercle
- HYBRIDS: with bright silvery-blue reflections as in the *Siphateles*, and approaching the *Gila* in the amount of gold; a trace of the golden bar behind preopercle in most hybrids (strong in one)
- *Siphateles:* with silvery blue and gold reflections, but with much less gold than in the *Gila;* no golden bar behind preopercle

REGION ABOUT BASE OF PAIRED FINS:
- *Gila:* translucent gold
- HYBRIDS: with some of this color
- *Siphateles:* (not noted, presumably almost colorless)

DORSAL FIN:
- *Gila:* dusky amber, in some fish with a wash of dull reddish or greenish
- HYBRIDS: (not recorded)
- *Siphateles:* olive to rich brown

LOWER FINS:
- *Gila:* with a wash of translucent gold, especially on the paired fins; yellower than in the *Siphateles*
- HYBRIDS: varying greatly; in some much as in the *Gila*, in others, about as in *Siphateles;* in still others, rich orange
- *Siphateles:* olive to rich brown basally, paling outward and with a bluish-white border

Preserved specimens (Pl. II) of *Gila* and *Siphateles* usually differ in coloration, and the hybrids tend to be recognizably intermediate. *Gila* specimens are usually rather dark in general tone, ordinarily show a trace of a dark lateral band, and are typically marked with variable dusky spots (regenerated scales). *Siphateles* specimens are commonly lighter, show little trace of a dusky lateral band, and are not marked with darkened scales; the dark margins of the scale pockets, however, tend to be better defined. The hybrids vary from the one extreme to the other, but commonly exhibit intermediate or mixed characters in their coloration.

EXPLANATION OF EXTREME CHARACTERS OF HYBRIDS

As noted above, the *Gila* × *Siphateles* hybrids are extreme, or tend to be so, in a number of characters. They have a longer and deeper head, bigger fins, and a deeper body (particularly above the axis) than one would expect to find, on the generally well-substantiated theory of hybrid intermediacy. The long distance between the origin of the dorsal fin and the lateral line is correlated with a high scale count along this line. Similarly, on the average the pectoral fin in the hybrid is larger and has more rays than it does in either parental species.

Something in the constitution of these hybrids would seem to grant them an especial development of the head region, of the body depth, and of the fins. We cannot refrain from thinking of this development as due to some factor other than the specific genes. It seems more plausible that a basic feature in the metabolism is responsible; that we are dealing with an expression of hybrid vigor. It will be recalled that the verified hybrids among the sunfishes (Centrarchidae) display what seems to be heterosis in their growth, activity, intensity of color, and heaviness of body (Hubbs and Hubbs, 1931–33). Certain of the *Gila* × *Siphateles* hybrids definitely recall some of the sunfish crosses in having an extreme development of the flesh, which has caused the body to be very robust and the nape region to bulge beyond the occiput. High development of the fins has characterized many of the aquarium-produced hybrids in the Poeciliidae.

The attribution of the large heads, deep body, and high fins of these cyprinid hybrids to heterosis finds support in the similarity of these differences to certain character gradients that are commonly

exhibited by fishes. Thus young fish usually differ from old ones in having the head and the fins proportionately larger (but with a slenderer body), and males differ from females in their bigger fins. Southern races typically differ from northern ones, and races living in highly productive waters often contrast with those inhabiting sterile waters by having deeper bodies, larger heads, and bigger fins (Hubbs, 1941b) — in other words, in the same way that the hybrids under treatment differ from the parental species.

EVIDENCE OF BACKCROSSING

There is no indication that the distinctions between *Gila orcuttii* and *Siphateles mohavensis* are being broken down by the mass hybridization between these genera. In a number of characters the hybrids show little overlap with either parental type, and the whole body of evidence on fish hybrids (Hubbs, 1940a: 205–209) leads us to expect that backcrossing, if it occurred, would cause the counts and measurements to overlap. The number of gillrakers is particularly characteristic of the hybrids (p. 360 and Table V), for only 8 per cent of the counts for the hybrids overlap slightly the range of counts for both parental species. The pelvic rays (Table VIII) are typically 8 in *Gila*, 9 in hybrids, and 10 in *Siphateles*. Studies on correlations of counts in species of fish yield no indication that the gillraker and pelvic-ray counts should show any positive correlation within a systematic unit (unless some hybridization is involved). When we examine these counts for the Mohave cyprinids, we find that such a correlation is indicated (Table XV). The Deep Creek specimens of *Gila* with 9 pelvic rays have a higher average number of gillrakers than those with 8 pelvics. The 8 individuals that agree with the hybrids in having 9 pelvic rays and approach them in having 10 gillrakers probably owe this combination of characters to hybridization followed by backcrossing. The hybrids from Afton Canyon show a definitely significant correlation between the number of pelvic rays and gillrakers ($r = 0.34 \pm 0.07$), which indicates that there are included a considerable number of backcrosses with *Gila* and a few with *Siphateles*.

Backcrossing with *Gila orcuttii* is suggested also by the correlation between extremely low (*Gila*-like) counts of gillrakers and a high number (again *Gila*-like) of pharyngeal teeth in the outer row. These again are unrelated characters with no expected correlation. Among

TABLE XV

CORRELATION BETWEEN NUMBER OF PELVIC RAYS AND NUMBER OF GILLRAKERS IN *GILA*, HYBRIDS, AND *SIPHATELES*

Locality		Lowest pool of Deep Creek				Mohave River in Afton Canyon			
No. of pelvic rays*		7	8	9	10	8	9	10	11
No. of gillrakers*	6	..	4	..	..	4	..	..	..
	7	2	22	..	..	15	3	..	..
Gila orcuttii...............	8	2	94	12	..	58	18	..	..
	9	..	42	2	..	29	13	..	..
	10	..	12	8	..	2	..	..	..
	8	..	..	..	..	2 †	2 †	..	..
	9	..	..	..	..	..	2 †	..	..
	10	..	..	4	..	6	18	2	..
	11	..	..	5	1	5	21	2	..
	12	..	2	24	4	..	14	..	..
HYBRIDS	13	..	2	35	17	..	21	9	..
	14	..	..	47	19	..	14	..	..
	15	..	1	20	11	..	2	2	..
	16	..	..	..	4	..	5	3	..
	17	..	..	2	2	..	7	3	..
	18	..	..	..	..	..	4	..	..
	18	..	..	4	..	..	..	..	..
	19	..	..	..	4	..	..	..	..
	20	..	..	1	3	..	..	2	..
	21	..	..	..	2	..	..	6	..
	22	..	..	2	8	..	11	5	..
Siphateles mohavensis	23	..	5	5	26	..	5	15	..
	24	..	..	5	35	..	15	25	2
	25	..	1	15	30	1	10	15	..
	26	..	..	10	28	..	5	9	..
	27	..	..	4	10	..	1	5	..
	28	..	..	6	2	..	..	..	..

* The pelvic rays were counted on both sides of all specimens. The gillrakers were enumerated for the right side only, except for three specimens of *Siphateles* from Deep Creek and for one *Gila*, twelve hybrids, and one *Siphateles* from Afton Canyon, which were counted on both sides. All possible combinations of counts were tallied.

† The hybrid with 8 gillrakers and the 2 with 9 rakers, on the right side, have 11 rakers on the left side (the entries are doubled because the pelvic rays were counted on both sides).

the hundreds of specimens counted there are only three hybrids with fewer than 10 gillrakers (on one side only), and two of these three

are among the four that have two teeth in the outer row on one or both sides. The data for the five specimens involved follow:

Gillrakers, 8–11; pharyngeal teeth, 1, 5—4, 1
Gillrakers, 8–11; pharyngeal teeth, 2, 4—5, 2
Gillrakers, 9–11; pharyngeal teeth, 1, 5—4, 2
Gillrakers, 12–12; pharyngeal teeth, 1, 5—4, 2
Gillrakers, 13–13; pharyngeal teeth, 1, 5—4, 2

No very extensive backcrossing is indicated, however. As a rule, the hybrids are probably first-generation products, with low fertility.

SUMMARY

The two native fishes of the Mohave River system, *Gila orcuttii* and *Siphateles mohavensis*, probably had a complementary distribution during the Pluvial period of the Quaternary, for the *Gila* is adapted for fluviatile life and the *Siphateles* for a lacustrine existence. Despite an obvious maladjustment, the *Siphateles* has been able to survive, with the *Gila*, in isolated creeks that now constitute the only permanent water in this river system. As a result of this cohabitation the two species have engaged in mass hybridization. Hybrids were estimated to constitute 8 per cent of the minnow population in the entire basin; in the area of mutual occurrence the hybrid ratio rose to 9. Interspecific hybridization in fishes is seldom carried to such a degree. Ordinarily it appears to be selected against, because of its biotic inefficiency. The breakdown of the isolating mechanism is apparently due to the circumstance that in these desert waters the physical rather than the biotic environment is dominant in the struggle for existence.

The intergeneric hybrids of the Mohave, like other hybrids between species of Western minnows [6] and of fishes in general, display their mixed origin by a variety of circumstantial evidence. The hybrid interpretation is in complete harmony with the ecological picture. The hybrids were more resistant than the *Siphateles*, but less so than the *Gila*, to the great flood of 1938. They show intermediacy in numerous characters of the pharyngeal arch and dentition, with a variability unexpected in a species. They exhibit similar intermediacy and variability in the length of the gill slit and in the number and form of the gillrakers. The scale structure is also transi-

[6] See papers by Hubbs and Schultz (1931), Schultz and Schaefer (1936), and Calhoun (1940). We have in preparation several additional papers, with conclusions similar to those here proposed.

tional. With a few noteworthy exceptions the scale and fin-ray counts interpose between those for the parental species. The fins and integument are less leathery than those in the *Gila*, but not so fragile as those in the *Siphateles*. Several critical ratios between different measurements provide further evidence of hybridity. The color is likewise intermediate. In general, the proportionate measurements yield averages that are intercalated between those for the parental species.

In certain respects, however, the hybrids are not intermediate. They are large-headed, deep-bodied, and big-finned. In some measurements they are more extreme in these respects than is either parental species. This is true, for example, of the pectoral fin and of the depth of the body above the lateral line, and these aberrant measurements are reflected, respectively, in an increased number of pectoral rays and of scales in the series between the origin of the dorsal fin and the lateral line. The extreme development of certain parts of the body in the hybrids we cannot attribute to the action of specific genes. The similar differences that appear in certain gradients, particularly those between southern races and northern ones, and between races dwelling in highly productive waters and ones existing in sterile habitats, lead us to believe that the aberrant features of the hybrids have some simple physiological basis. We attribute their extremely big heads, robust bodies, and large fins to heterosis.

There is evidence of a small amount of backcrossing between the hybrids and the parental species, particularly with the *Gila*. Certain unrelated counts, which happen to be low in the *Gila* and high in the *Siphateles*, show a positive correlation that would probably not have arisen in any way other than by backcrossing.

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FIG. 1. *Gila orcuttii* FIG. 2. Hybrid FIG. 3. *Siphateles mohavensis*

All scales are of adults

FIG. 4. Lowest pool of Deep Creek, photographed by Laura C. Hubbs on September 1, 1934, when the entire fish population was removed and preserved for the analysis of the natural hybrids

EXPLANATION OF PLATE II

FIGS. 1–3. Adult females from Deep Creek, collected September 1, 1934

FIG. 1. *Gila orcuttii*, 78 mm. in standard length

FIG. 2. Hybrid, 87 mm. long

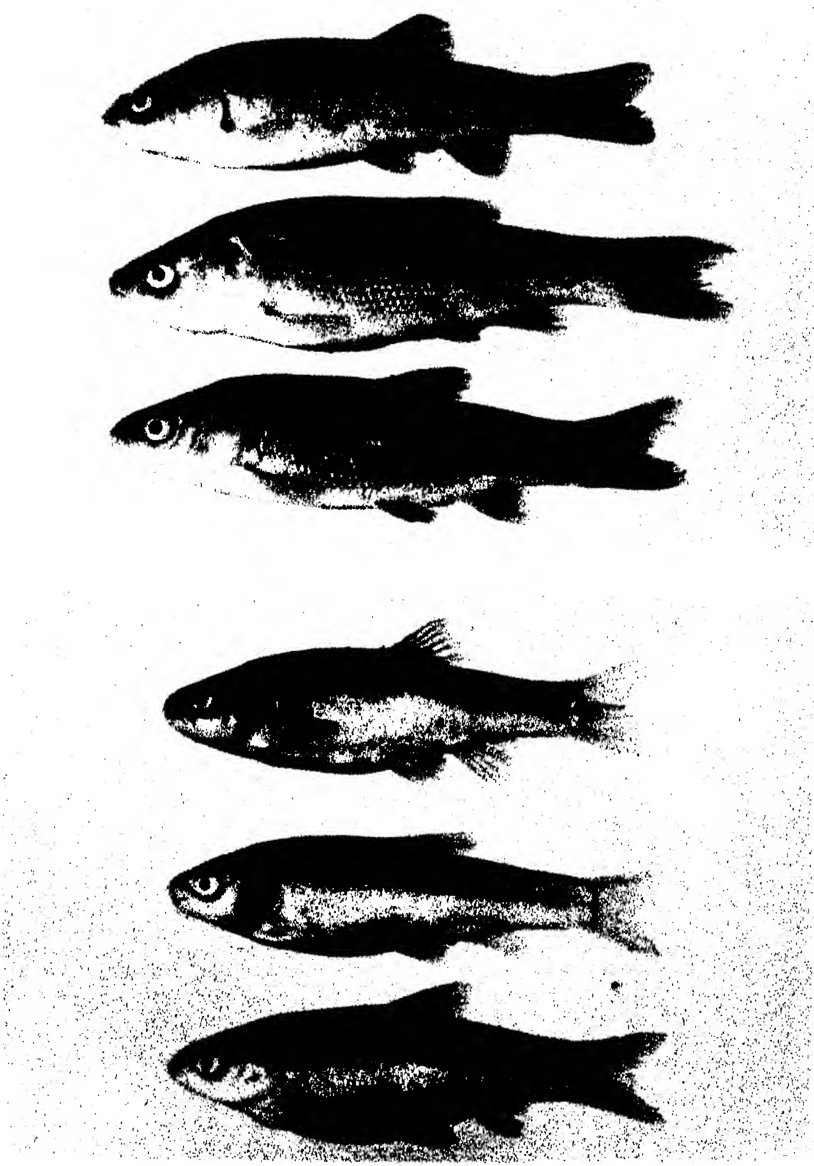
FIG. 3. *Siphateles mohavensis*, 79 mm. long

FIGS. 4–6. Adults from Afton Canyon (main stream), collected April 6, 1939; 57–58 mm. in standard length

FIG. 4. *Gila orcuttii*, male

FIG. 5. Hybrid, female

FIG. 6. *Siphateles mohavensis*, female



1

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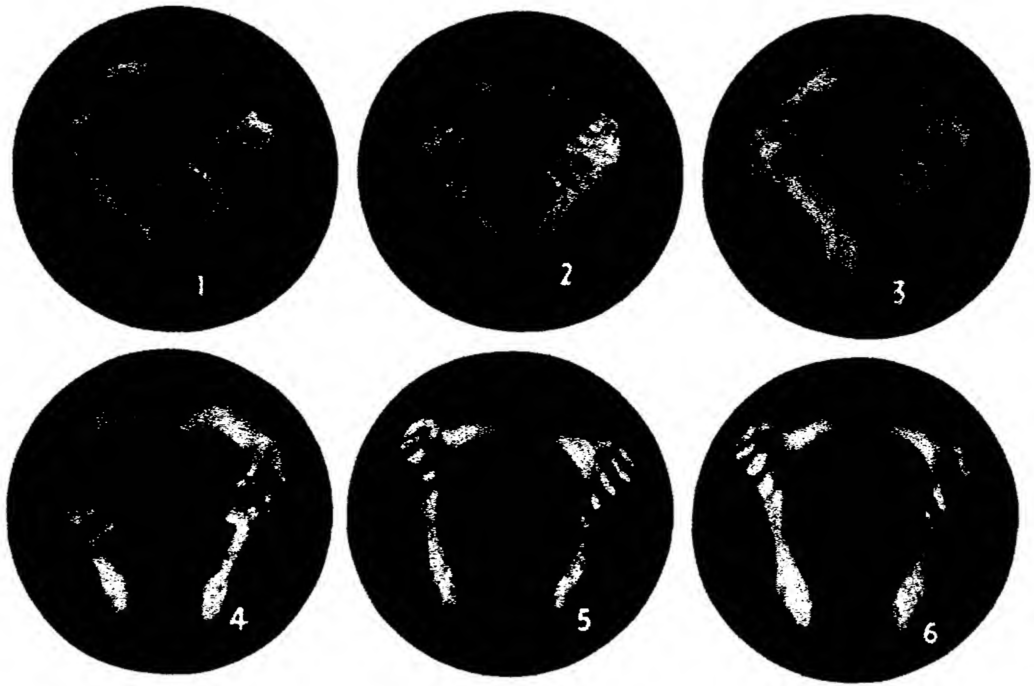
5

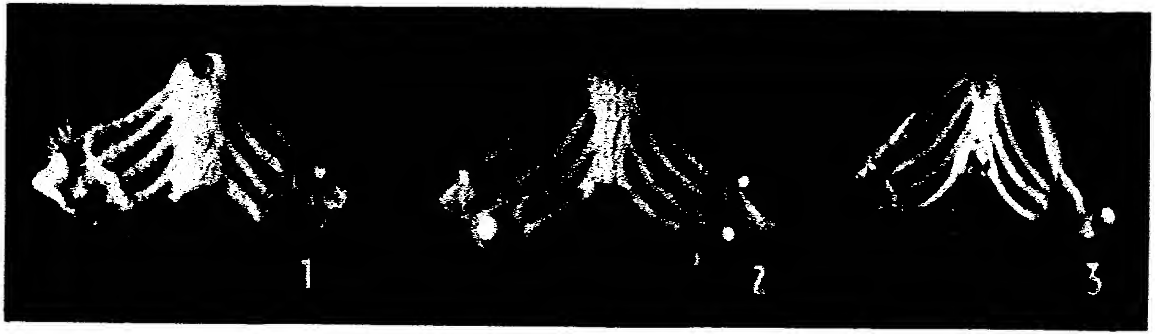
6

Gila orcuttii, hybrids, and *Siphateles mohavensis* (photographs by Clarence Flaten)



Pharyngeal arches and teeth of *Gila*, hybrids, and *Siphateles* from adults 71–75 mm. long (photographs by Clarence Flaten)

FIGS. 1, 4. *Gila orcuttii*. Teeth, 2, 5 — 4, 2 (one missing on left side represented by alveolus)
FIGS. 2, 5. Hybrid. Teeth, 1, 5 — 5, 1
FIGS. 3, 6. *Siphateles mohavensis*. Teeth, 0, 5 — 5, 0 (one missing on right side represented by alveolus)



Gila orcuttii Hybrid *Siphateles mohavensis*

Gill arches of adult minnows, 91–99 mm. long

THE MOSQUITOES OF THREE SELECTED AREAS IN CHEBOYGAN COUNTY, MICHIGAN *

WILLIAM H. IRWIN

INTRODUCTION

THE data upon which this paper is based are part of the results of a mosquito survey of three areas in Cheboygan County, Michigan. Larvae and adults were collected from early spring until autumn, and the waters in which the larvae grew were analyzed in an endeavor to learn something of their habitat distribution. Owing to the large amount of time consumed in this type of investigation only three areas were selected for intensive study. Mud Lake, Inverness Township, Cheboygan County, Michigan (T. 37 N., R. 2 W. 1st P. M., Secs. 7 and 18), and Bryant's Bog, Cheboygan County, Michigan (T. 37 N., R. 3 W. 1st P. M., Secs. 29 and 30), were chosen first because of their extensive characteristic bog formations, which impound innumerable pools during the spring and early summer of each year. Later, the eastern shore area (area of the Biological Station of the University of Michigan) of Douglas Lake, Cheboygan County, Michigan, was included. Collections were made during the summers from 1935 to 1939 and the springs from 1937 to 1939. Analyses were made of the waters from which larvae were collected during the spring and summer of 1938 and 1939.

The literature on Michigan mosquitoes is scanty. Pettit (1903) reported a few species from Ingham County. Hinman (1935) confirmed Pettit's record of *Uranotaenia sapphirina* Osten Sacken for Michigan by reporting it from Dexter, Michigan. Dyar (1922) recorded one species that had been sent to him by the Army Medical Board at Camp Custer. Matheson (1924) listed several species from Cheboygan County. Jewell and Brown (1929) reported two species

* Contribution from the Biological Station and the Department of Zoölogy, University of Michigan.

from Mud Lake, Cheboygan County. McDaniel (1932) gave a list of species that probably occur in Michigan. Irwin (1941) published a list of forty-three species known to occur in the state.

The writer is indebted to Professor Paul S. Welch, under whose direction the work was done, and to Professor Robert Matheson for permission to work in the mosquito collection at Cornell University and for his verification of certain identifications.

SITUATIONS STUDIED

Except for the lakes mentioned all waters studied were shallow. No pools were found having a depth greater than one meter. Their depths ranged from a few centimeters to about one meter. The bottoms were littered with decomposing leaves, twigs, and humus. Each pool commonly contained débris originating from the surrounding vegetation. Most of the waters were strongly colored and highly turbid. All pools began to dry by evaporation as soon as the ice melted in the spring; this caused concentrations of aquatic life and suspended matter.

Mud Lake

Descriptions of Mud Lake by Goe, Erickson, and Woollett (1925), Jewell and Brown (1929), and Welch (1936a) make unnecessary any general account of it here. For present purposes it is desirable to point out that the lake is surrounded by a large mat, grounded at the periphery and floating at its lakeward edges; that this mat is narrow on one side of the lake and very expansive on the other; that most of of it is of either the Chamaedaphne-Sphagnum or the Carex type; and that this great area of mat impounds extensive quantities of water. For descriptions of subdivisions and the physicochemical features of these waters see Irwin (1942).

Bryant's Bog

Bryant's Bog is near the southwest shore of Douglas Lake, Cheboygan County, Michigan. It has been the subject of many studies during the past thirty years. (For bibliography see Welch, 1936b.) For the purposes of this paper it is necessary only to point out that the major portion of the bog is occupied by an extensive mat enclosing at its center a small remnant of the original open water. The mat is for the most part a mixture of sedges and sphagnum moss.

Pools on the mat are similar to those at Mud Lake, but the temporary ones at the margin between the aspens and the mat ("marginal ditch") are larger and deeper and persist longer during spring. For the physicochemical features of the waters of these pools see Irwin (1942).

Biological Station Area

Since the time available did not allow investigation of the entire Douglas Lake area pools in the vicinity of the University of Michigan Biological Station were chosen for study. The area included about two and one-half miles of shore line at the southeast corner of the lake. Physiographically these situations are distinctly different from the bogs. The pools are confined to the shore area and consist mainly of old beach pools flooded by rains and melting ice and snow. In early spring the pools are not in deep shade, but later on the shade becomes dense over most of the water. The pools covered a larger area, were deeper, and were more exposed to the wind than pools in the bog areas. These conditions caused the water to warm slowly but uniformly.

Grapevine Point

Grapevine Point is a wooded tract of land situated west of the station site and extending to the lake. It has beach pools on its northern and western shores which seldom remain throughout the

TABLE I

PHYSICOCHEMICAL DATA FROM POOLS OF THE GRAPEVINE POINT AREA, 1939

Date	Type of pool	Water depth cm.	Temp. C.	pH	O_2 c.c. per l.	CO_2 p.p.m.	Methyl orange alkalinity p.p.m.	Conductivity reciprocal megohms
5-11	Beach	60	10.0	6.5	1.7	5.0	122.0	225
5-11	Beach	90	13.0	6.5	3.6	3.1	123.0	220
5-11	Beach	75	12.0	7.3	2.7	9.3	120.0	225
5-11	Beach	25	15.0	7.3	4.6	9.7	94.0	250
5-29	Beach	45	15.0	5.6	1.5	7.4	115.0	290
5-29	Beach	75	15.0	5.9	1.5	5.0	130.0	250
5-29	Beach	45	15.0	5.0	2.0	15.0	101.0	200
5-29	Beach	5	20.0	5.9	0.0	28.0	94.0	200
6-17	Beach	15	15.0	6.0	0.1	10.0	135.0	260
6-17	Beach	45	18.0	7.1	1.2	8.0	140.0	300

summer, but in early spring one on the west shore is about 100 meters long and 15 meters wide and has a maximum depth of 1 meter. The other pools are smaller and shallower. Some on the northern end of the peninsula are completely shaded when the trees are in foliage. Others lying parallel to the shore line are shallower still and, consequently, their waters warm more quickly. The bottoms of the pools, which are composed of sand covered with humus, support trees and shrubs. After drying these areas produce herbs similar to those on the surrounding forest floor. For the physicochemical features of these pools see Table I.

Pine Point

About a mile north of the Station, on the east shore of the lake, a group of four pools occurs on an area called Pine Point. A long semipermanent one extends northeastward from near shore until it

TABLE II

PHYSICOCHEMICAL DATA FROM POOLS OF THE PINE POINT AREA, 1939

Date	Type of pool	Water depth cm.	Temp. C.	pH	O_2 c.c. per l.	CO_2 p.p.m.	Methyl orange alkalinity p.p.m.	Conductivity reciprocal megohms
5–12	Sandpit	45	18.0	5.9	5.2	4.2	8.0	95
5–12	Beach	37	15.0	5.4	1.7	26.2	0.0	45
5–12	Beach	45	21.0	6.0	4.0	13.2	11.0	50
5–30	Sandpit	30	18.0	5.6	4.0	7.5	7.5	57
5–30	Beach	30	18.0	5.8	0.3	10.0	0.0	75
5–30	Beach	37	18.5	5.5	4.4	29.0	3.0	135

merges with a swamp one-half mile distant. It has a maximum depth of 0.5 meter and is a semimarsh supporting trees, shrubs, and emergent aquatic plants. Another depression, formed by excavation of sand, contains water during the greater part of spring. The remaining two are beach pools. One lies parallel to the shore line, is nearly one meter deep, and is so overgrown with shrubs that it is shaded even before the leaves are out. The other is not more than 30 cm. deep in early spring and soon dries, although it covers a considerable area. For the physicochemical features of these pools see Table II.

DISCUSSION OF SPECIES

Genus *Aedes* Meigen

Adult mosquitoes of the genus *Aedes* first appeared about the middle of May and by the last of the month were very numerous in wooded regions. They migrated from their breeding pools to all surrounding areas, but remained only where there were an abundance of green vegetation and protection from wind. During the last of May and the first of June many species entered houses, but did not remain, as do some species of Anophelini. Many species occurred in the pools throughout the remainder of spring and summer. Usually there was but one brood a year, and the number of adults decreased rapidly as the season progressed. Lights seemed to attract them very little, though they would cluster around a warm dish as eagerly as around an animal and would try energetically to insert their mouth parts. They were more inclined to attack when the humidity was high and the air warm. Except during unusually mild nights in early spring their attacks stopped about 10:00 P.M. and began about 4:00 A.M., unless they were disturbed. As the morning advanced beyond eight o'clock they retreated to the shaded and more humid areas of trees, where they stayed until late afternoon.

1. *A. aboriginis* Dyar. — Rare for this region; three females taken at Bryant's Bog, May 28, and two at Mud Lake, June 12, 1938; no larvae or males found.

2. *A. aurifer* (Coquillett). — One adult taken at Mud Lake, July 12, 1937; two larvae collected from large mat pools, Mud Lake, May 14, 1938.

Dyar (1922; 1928) states that the larvae live in cranberry bogs particularly, but apparently this is not true for northern Michigan.

Immature specimens of *A. aurifer* taken from waters with principal chemical features as follows: pH, 5.5; dissolved oxygen, 1.5 c.c. per l.; free carbon dioxide, 2.7 p.p.m.; methyl orange alkalinity, 20.0 p.p.m.; conductivity, 42 reciprocal megohms.

3. *A. canadensis* (Theobald). — Adults abundant; taken as early as May 14, 1938, and as late as August 21, 1938. Larvae very abundant and in every natural situation investigated; greatest concentrations in pools on sphagnum mats; earliest seasonal record, April 30, 1938, latest, August 6, 1937; the later seasonal collections made from cold permanent swamp pools.

Immature specimens of *A. canadensis* taken from waters with principal chemical features as follows: pH, 4.0–7.3; dissolved oxygen, 0.0–8.9 c.c. per l.; free carbon dioxide, 1.8–36.5 p.p.m.; methyl orange alkalinity, 0.0–130.0 p.p.m.; conductivity, 37–290 reciprocal megohms.

4. *A. cinereus* Meigen. — Very common; earliest seasonal collections of adults at Mud Lake and in Douglas Lake area, May 29, 1937 and 1939; found during summer; latest seasonal record, August 21, 1938; never taken far from breeding places; usually fly low, about one meter above ground.

First collections of fourth instar larvae taken 10–14 days later than earliest maturing *Aedes* larvae; found in all natural pools except more acid ones of Bryant's Bog mat; most numerous in shallow pools or at margins of deeper ones; earliest seasonal record, May 8, 1939, latest, June 24, 1937.

Immature specimens of *A. cinereus* taken from waters with principal chemical features as follows: pH, 5.0–7.3; dissolved oxygen, 0.0–4.7 c.c. per l.; free carbon dioxide, 1.5–19.5 p.p.m.; methyl orange alkalinity, 0.0–130.0 p.p.m.; conductivity, 42–290 reciprocal megohms.

5. *A. communis* (DeGeer). — Abundant; earliest seasonal record for adults, May 14, 1938, latest, August 3, 1935 and 1936; specimens taken throughout each summer.

Larvae abundant; in all natural pools, particularly in early-drying pools among aspens, beach pools of Douglas Lake area, and shallow swamp pools; absent in pools with abundance of filamentous algae; earliest seasonal record, April 30, 1938, latest, June 29, 1937; scarce during June; all records for June from cool swamp pools.

Immature specimens of *A. communis* taken from waters with principal chemical features as follows: pH, 5.5–7.3; dissolved oxygen, 0.0–5.2 c.c. per l.; free carbon dioxide, 1.5–26.2 p.p.m.; methyl orange alkalinity, 0.0–122.0 p.p.m.; conductivity, 37–225 reciprocal megohms.

6. *A. diantaeus* Howard, Dyar, & Knab. — Two females taken at Mud Lake, June 12, 1937. Larvae fairly common; earliest seasonal record, April 30, 1938, latest, May 28, 1938.

Immature specimens of *A. diantaeus* taken from waters with principal chemical features as follows: pH, 4.0–6.0; dissolved oxygen, 0.6–5.2 c.c. per l.; free carbon dioxide, 1.9–26.9 p.p.m.; methyl

orange alkalinity, 0.0–34.0 p.p.m.; conductivity, 45–155 reciprocal megohms.

7. *A. excrucians* (Walker). — Adults abundant throughout areas studied; invaded houses in evenings and early mornings, but restricted to wooded regions during day; will attack day or night; earliest seasonal record, May 30, 1939; adults still abundant August 21, 1938.

Larvae common in all natural pools examined, but more abundant in partly shaded ones; earliest seasonal record, April 30, 1938, latest, May 29, 1937.

Immature specimens of *A. excrucians* taken from waters with principal chemical features as follows: pH, 4.0–6.5; dissolved oxygen, 0.0–8.9 c.c. per l.; free carbon dioxide, 1.5–19.5 p.p.m.; methyl orange alkalinity, 0.0–123.0 p.p.m.; conductivity, 37–220 reciprocal megohms.

8. *A. fitchii* (Felt & Young). — Most abundant adult mosquitoes in areas studied; are restricted to the wooded regions during day, but migrate to all parts at night; earliest seasonal record, May 29, 1939, latest, August 21, 1938.

Larvae rare within areas investigated; only four specimens taken, three from mat pools of Mud Lake (1, May 8, 1937; 2, May 14, 1938) and one from beach pool, Pine Point, Douglas Lake area, May 12, 1939.

Immature specimens of *A. fitchii* taken from waters with principal chemical features as follows: pH, 5.5–6.1; dissolved oxygen, 1.4–4.0 c.c. per l.; free carbon dioxide, 2.7–13.2 p.p.m.; methyl orange alkalinity, 11.0–20.0 p.p.m.; conductivity, 42–50 reciprocal megohms.

9. *A. flavescens* (Müller). — Adults not found in areas studied; ten larvae taken in beach pools of Biological Station area; earliest seasonal record, May 12, 1939, latest, May 29, 1939.

Immature specimens of *A. flavescens* taken from waters with principal chemical features as follows: pH, 5.6–6.1; dissolved oxygen, 1.5–4.0 c.c. per l.; free carbon dioxide, 5.0–13.2 p.p.m.; methyl orange alkalinity, 11.0–130.0 p.p.m.; conductivity, 50–290 reciprocal megohms.

10. *A. impiger* (Walker). — Rare; adults found in areas investigated during morning and afternoon in wooded sections, but about buildings of Biological Station only in evenings; earliest seasonal record, May 14, 1938, latest, June 12, 1937.

One larva only taken at Mud Lake, from large mat pool exposed to sun; none found at Bryant's Bog; several collected from beach pool at Grapevine Point, Biological Station area; earliest seasonal record, May 11, 1939, latest, May 29, 1937.

Chemical records of water made from beach pool: pH, 7.3; dissolved oxygen, 2.7 c.c. per l.; free carbon dioxide, 9.3 p.p.m.; methyl orange alkalinity, 120.0 p.p.m.; conductivity, 225 reciprocal megohms.

11. *A. implacabilis* (Walker). — The writer found it impossible to separate the females of *A. implacabilis* from those of *A. punctor* (Kirby). Specimens of both species were reared, but no distinguishing characters for the females could be found. To judge from the proportionate number of larvae of the two species, females of *A. implacabilis* must have been common.

Larvae plentiful at Mud Lake and Bryant's Bog; not found in Biological Station area; first to mature in spring; occurred mainly in sunlit pools; few in shaded swamp pools; comprised about 6 per cent of all larvae taken at Mud Lake and approximately 5 per cent of those at Bryant's Bog; earliest seasonal record, April 30, 1938, latest, May 22, 1937.

Immature specimens of *A. implacabilis* taken from waters with principal chemical features as follows: pH, 4.0–6.1; dissolved oxygen, 1.0–4.7 c.c. per l.; free carbon dioxide, 1.9–19.5 p.p.m.; methyl orange alkalinity, 0.0–20.0 p.p.m.; conductivity, 37–155 reciprocal megohms.

12. *A. intrudens* Dyar. — Adults abundant throughout spring and summer; earliest seasonal record, May 12, 1939, latest, August 10, 1935.

There is a wide variation in the characters used for taxonomy. About 50 per cent of adults collected lacked the lower mesepimeral bristles given as a character in the key by Matheson (1929).

Larvae abundant locally; absent at Mud Lake; not taken at Bryant's Bog during spring of 1937, but abundant in that area in pools among aspens and on mat during spring of 1938; abundant in beach pools at Pine Point, Douglas Lake, 1939; earliest record, April 30, 1938, latest, May 12, 1939.

Immature specimens of *A. intrudens* taken from waters with principal chemical features as follows: pH, 4.0–5.9; dissolved oxygen, 0.0–5.2 c.c. per l.; free carbon dioxide, 2.4–26.2 p.p.m.; methyl

orange alkalinity, 0.0–8.0 p.p.m.; conductivity, 45–110 reciprocal megohms.

13. *A. lateralis* (Meigen). — Adults fairly common; earliest seasonal record, May 14, 1938, latest, July 30, 1937; both males and females taken throughout areas studied; adults were small, about the size of those of *A. canadensis* (Theobald), yet, contrary to the statement by Dyar (1922), not able to crawl through ordinary window screens.

First mature larvae found at Bryant's Bog and Mud Lake, May 8, 1937, and in Biological Station area, May 12, 1939; latest seasonal collection, May 29, 1939. Larvae absent from more acid waters of Bryant's Bog mat. Dyar (1922) states they are found in shaded pools, but most of those collected by the writer were from sunlit pools. However, a few specimens were taken in shaded and partly shaded areas.

Immature specimens of *A. lateralis* taken from waters with principal chemical features as follows: pH, 5.4–6.0; dissolved oxygen, 1.7–5.2 c.c. per l.; free carbon dioxide, 4.2–26.3 p.p.m.; methyl orange alkalinity, 0.0–11.0 p.p.m.; conductivity, 45–155 reciprocal megohms.

14. *A. pullatus* (Coquillett). — Rare; two females taken at Bryant's Bog, May 14, 1938, and May 22, 1937; one female at Mud Lake, May 5, 1938.

One larva found in large mat pool at Mud Lake, May 14, 1938; taken from water with principal chemical features as follows: pH, 5.5; dissolved oxygen, 1.4 c.c. per l.; free carbon dioxide, 2.7 p.p.m.; methyl orange alkalinity, 20.0 p.p.m.; conductivity, 42 reciprocal megohms.

15. *A. punctor* (Kirby). — Owing to the writer's inability to distinguish females of *A. punctor* from those of *A. implacabilis* in field collections of adults (see No. 11) the exact magnitude of the populations of each species was uncertain. *A. punctor* females of known identity were secured only by rearing them from previously identified larvae.

Adults apparently abundant; taken in wooded regions day or night; found in and around buildings only during early morning and evening; among first to emerge in spring; earliest seasonal record, May 14, 1938, latest, August 2, 1938.

Larvae abundant in all situations at Bryant's Bog and Mud Lake;

not found in Biological Station area; numerous in cold, shaded swamp pools as well as in exposed pools of mat and aspens; later seasonal records from the cold, shaded pools; earliest seasonal record, April 30, 1938, latest, July 2, 1937.

Immature specimens of *A. punctor* were taken from waters with principal chemical features as follows: pH, 4.2–6.1; dissolved oxygen, 0.0–8.9 c.c. per l.; free carbon dioxide, 1.5–19.5 p.p.m.; methyl orange alkalinity, 0.0–48.0 p.p.m.; conductivity, 35–170 reciprocal megohms.

16. *A. riparius* Dyar & Knab. — Rare; only one male (May 22, 1937) and one female (July 7, 1938) taken; larvae not found.

17. *A. spenceri* (Theobald). — Rare; one female taken at Mud Lake, July 30, 1937; one larva collected in large mat pool, Mud Lake, May 14, 1938; one larva from mat pool, Bryant's Bog, May 22, 1937. Other specimens taken from areas bordering localities noted here.

One larva taken from water with principal chemical features as follows: pH, 5.5; dissolved oxygen, 1.4 c.c. per l.; free carbon dioxide, 2.7 p.p.m.; methyl orange alkalinity, 20.0 p.p.m.; conductivity, 42 reciprocal megohms. Chemical analyses of water containing other larva not available.

18. *A. sticticus* (Meigen). — Adults rare; not taken beyond shelter of woods except in evening; earliest seasonal record, May 14, 1938, latest, August 2, 1938.

One larva found, May 14, 1938, in shaded permanent swamp pool at Mud Lake, the principal chemical features of which were: pH, 5.0; dissolved oxygen, 0.0 c.c. per l.; free carbon dioxide, 1.5 p.p.m.; methyl orange alkalinity, 20.0 p.p.m.; conductivity, 55 reciprocal megohms.

19. *A. stimulans* (Walker). — Adults abundant throughout spring and summer; earliest seasonal record, May 29, 1939, latest, August 21, 1938; specimens taken in wooded areas day or night after the vegetation had been disturbed; found about buildings and in houses only in early morning and evening hours; commonly associated with *A. fitchii* and *A. excrucians*.

Larvae abundant in beach pools at Grapevine Point and Pine Point, Biological Station area; one specimen only taken in large mat pool at Mud Lake; larvae of thirteen other species found in association with larvae of this species; earliest seasonal record, May 11, 1939, latest, May 29, 1937.

Immature specimens of *A. stimulans* taken from waters with principal chemical features as follows: pH, 5.4–7.3; dissolved oxygen, 1.7–4.6 c.c. per l.; free carbon dioxide, 5.0–26.2 p.p.m.; methyl orange alkalinity, 0.0–122.0 p.p.m.; conductivity, 45–250 reciprocal megohms.

20. *A. trichurus* (Dyar). — Common; adults appear early in spring and are present throughout summer; enter houses in early spring; found in wooded regions until early summer, when their numbers decrease noticeably; earliest seasonal record, May 14, 1938, latest, August 10, 1935.

Larvae absent in more acid pools of Bryant's Bog mat; present in most parts of areas studied; earliest seasonal record, April 30, 1938, latest, May 14, 1938.

Immature specimens of *A. trichurus* taken from waters with principal chemical features as follows: pH, 4.2–7.3; dissolved oxygen, 0.0–4.6 c.c. per l.; free carbon dioxide, 1.5–26.2 p.p.m.; methyl orange alkalinity, 0.0–123.0 p.p.m.; conductivity, 37–250 reciprocal megohms.

21. *A. vexans* (Meigen). — Adults not common; fly low, remaining close to ground; taken at various times of day; enter houses only at night; earliest seasonal record, June 26, 1938, latest, August 21, 1938.

Larvae taken in two collections from permanent swamp pools at Mud Lake, June 12, 1937, and from deep shaded pool on mat at Bryant's Bog, May 8, 1937; no chemical analyses of water available.

Unidentified *Aedes* larvae: Two groups of larvae that could not be identified as belonging to any known species were taken in these areas. In all keys these larvae were traced to *A. diantaeus* Howard, Dyar, & Knab, but the descriptions of that species do not fit. Since they have characters so strikingly distinct the following descriptions are given. Reared adults were not secured.

22. *Aedes sp.* — Two specimens collected from pools among aspens at Bryant's Bog, May 22, 1937; water analyses not available.

Description. — Head: wider than long. Antennae: longer than head, slightly enlarged basally, spines fairly large and scattered, 4-haired tuft at middle. Head hairs: upper, 3–4; lower, 3, anteantennal tuft of 2–4 hairs. Lateral abdominal hairs: double on first segment, single on 2–6. Scales of eighth abdominal segment: 11–12, arranged in triangular patch, each scale with long central spine.

Anal segment: longer than wide, not ringed by large plate, dorsal brush of 2 tufts and 2 long hairs, ventral brush of well-developed tufts. Air tube: three times as long as wide, tapering, pecten before middle with 3 detached teeth, pecten tuft of 5–6 hairs located at middle. Anal gills: about twice as long as anal segment, tapering to sharp point.

23. *Aedes sp.* — These specimens were collected from large mat pools at Bryant's Bog and Mud Lake. The earliest seasonal record was April 30, 1938, latest, May 14, 1938. Larvae taken during 1937 and 1939.

All collections of this species were from waters with principal chemical features as follows: pH, 4.0–5.9; dissolved oxygen, 3.4–8.9 c.c. per l.; free carbon dioxide, 2.4–7.5 p.p.m.; methyl orange alkalinity, 0.0–48.0 p.p.m.; conductivity, 40–155 reciprocal megohms.

Description. — Head: rounded, wider than long. Antennae: longer than head, coarsely spined toward tip, 2-haired tuft at middle. Head hairs: upper and lower 1–2 per trichopore, anteantennal tuft of 2–3 hairs. Lateral abdominal hairs: double on segments 1 and 2, single on 3–6. Scales of eighth abdominal segment: 5–7, arranged in one irregular row, sometimes one or two conspicuously out of line; each scale with long central spine. Anal segment: longer than wide, not completely ringed by plate, dorsal brush with one pair of long hairs and one pair of tufts consisting of 3–4 hairs each, ventral brush well developed. Air tube: at least four times as long as wide, tapering, pecten reaching middle and ending in 3 enlarged detached teeth, pecten tuft of 3–5 small hairs located beyond pecten and middle. Anal gills: pointed, twice as long as anal segment. All hairs of larva nearly uniform in diameter from base to apex, decidedly blunt at apex.

Genus *Anopheles* Meigen

The genus *Anopheles* is represented by three species. There are situations within the county that are well adapted for the growth of Anophelini, but they do not lie within the areas under discussion. Most permanent pools harbor a few larvae, however. Specimens were occasionally taken from beach, swamp, and mat pools, but most frequently from the lakeward margin of the mats. Larvae were not found before the middle of May. In these areas no larvae were collected from water totally exposed to the sun.

24. *A. maculipennis* Meigen. — Most common species found in areas studied; earliest seasonal record for adults, June 18, 1939.

Larvae in all natural pools during summer; specimens taken in margins of Mud Lake and Bryant's Bog; also in mat pools, permanent swamp pools, and beach pools in Biological Station area; earliest seasonal record, May 28, 1938, when only young instars were found; larvae present throughout summer.

Immature specimens of *A. maculipennis* taken from waters with principal chemical features as follows: pH, 4.8–5.1; dissolved oxygen, 0.0–0.7 c.c. per l.; free carbon dioxide, 1.5–2.1 p.p.m.; methyl orange alkalinity, 9.0–14.0 p.p.m.; conductivity, 65–70 reciprocal megohms.

25. *A. punctipennis* (Say). — Rare; scattered records of adults obtained throughout summers; earliest seasonal collection of adults, July 7, 1935.

Larvae present scantily in most natural pools in June, July, and August; earliest seasonal collection was of early instars from large mat pools at Mud Lake, May 28, 1938; occasional specimen in lakeward edges of mat in both Mud Lake and Bryant's Bog.

Immature specimens of *A. punctipennis* taken from waters with principal chemical features as follows: pH, 5.1–6.2; dissolved oxygen, 0.0–0.7 c.c. per l.; free carbon dioxide, 1.8–2.1 p.p.m.; methyl orange alkalinity, 0.0–114.0 p.p.m.; conductivity, 47–290 reciprocal megohms.

26. *A. walkeri* Theobald. — Very rare; one female taken at Mud Lake, August 24, 1938; adults common in localities but a few miles distant.

Genus *Culex* Linnaeus

There are four species of the genus *Culex* in the areas studied. Adults appeared about the last of June and were usually present until late autumn.

27. *C. apicalis* Adams. — Abundant; hide in dark recesses of stumps and logs, but most common on green vegetation; not found in or about buildings.

Larvae abundant in all pools after early June; earliest seasonal record, May 28, 1938; present in swamp pools, mat pools, beach pools, and the margins of Mud Lake and Bryant's Bog during June, July, and August.

Immature specimens of *C. apicalis* taken from waters with principal chemical features as follows: pH, 5.0–6.2; dissolved oxygen,

0.0–3.3 c.c. per l.; free carbon dioxide, 1.5–17.5 p.p.m.; methyl orange alkalinity, 0.0–130.0 p.p.m.; conductivity, 47–290 reciprocal megohms.

There is a variation in the number of head hairs of the larvae taken here. Many have two hairs at each trichopore; other specimens were found with hairs arranged in all possible combinations of one to two at each trichopore for both upper and lower head hairs. Repeatedly specimens with such variations were reared. Adults, male and female, coming from these larvae could not be distinguished from those coming from larvae with but one hair to a trichopore.

28. *C. pipiens* Linnaeus. — Rare; taken only from large mat pools at Mud Lake, June 26, 1938. The only adults secured were reared from this collection. Principal chemical features of water were: pH, 6.2; dissolved oxygen, 0.7 c.c. per l.; free carbon dioxide, 1.8 p.p.m.; methyl orange alkalinity, 114.0 p.p.m.; conductivity, 290 reciprocal megohms.

29. *C. restuans* Theobald. — Abundant; adults found in all localities from last of June to early autumn; earliest seasonal record, June 28, 1937.

Larvae abundant in all quiet natural pools and artificial containers; earliest seasonal record, May 28, 1939, when larvae were taken from large mat pool, Mud Lake; specimens collected almost at will after middle of June from any water supply; found in waters at margins in Mud Lake and Bryant's Bog, in both large and small mat pools, and intermittently in the drain basin of the Biological Station septic tank. When oiling was neglected the water in this basin, rich in organic matter, produced great numbers of mosquitoes. Actual count showed 256 larvae in one cup of the water. By the use of traps to capture emerging adults the pool was found to be producing at least 75 adults per square foot (154.8 sq. cm.) of water surface per hour.

Immature specimens of *C. restuans* taken from water with principal chemical features as follows: pH, 5.0–6.6; dissolved oxygen, 0.4–4.3 c.c. per l.; free carbon dioxide, 1.8–30.5 p.p.m.; methyl orange alkalinity, 6.0–11.4 p.p.m.; conductivity, 60–290 reciprocal megohms.

30. *C. salinarius* Coquillett. — Two larvae found in beach pool at Grapevine Point, Biological Station area, July 20, 1936; adults reared from the larvae, no analyses of water available.

Genus *Mansonia* Blanchard

There was only one representative of the genus *Mansonia*.

31. *M. perturbans* (Walker) is a common mosquito. Specimens could be captured any time during the day or night. They were taken throughout each summer for five years. The writer's earliest seasonal record is June 25, 1939; latest, August 18, 1939. No larvae were found.

Genus *Theobaldia* Neveu-Lemaire

Three species of the genus *Theobaldia* were found within the three areas.

32. *T. impatiens* (Walker). — Rare; one female taken at Mud Lake, August 21, 1938; larvae collected once from large mat pool at Mud Lake, June 26, 1938; adults reared from these larvae; associated with *Anopheles maculipennis, Culex apicalis, C. restuans, C. pipiens*, and *Theobaldia inornata*.

The principal chemical features of water were: pH, 6.2; dissolved oxygen, 0.7 c.c. per l.; free carbon dioxide, 1.8 p.p.m.; methyl orange alkalinity, 114.0 p.p.m.; conductivity, 290 reciprocal megohms.

33. *T. inornata* (Williston). — Rare; two larvae taken from large mat pool at Mud Lake, June 26, 1938, and reared. The principal chemical features of water were: pH, 6.2; dissolved oxygen, 0.7 c.c. per l.; free carbon dioxide, 1.8 p.p.m.; methyl orange alkalinity, 114.0 p.p.m.; conductivity, 290 reciprocal megohms.

34. *T. morsitans* (Theobald). — Rather common at Mud Lake; occasional specimens taken in Biological Station area; none found at Bryant's Bog. Adults could not be induced to eat blood meals, but were captured at their resting places, on the bases of trees and stumps near breeding pools.

Larvae common in all deeper pools of Mud Lake mat and swamp; a few taken from shaded portions of beach pool at Pine Point, Douglas Lake; earliest seasonal record (early instar larvae), Mud Lake, May 12, 1939, latest (mature larvae), August 6, 1937.

Immature specimens of *T. morsitans* taken from water with principal chemical features as follows: pH, 4.9–6.0; dissolved oxygen, 0.0–8.9 c.c. per l.; free carbon dioxide, 1.5–36.5 p.p.m.; methyl orange alkalinity, 0.0–36.0 p.p.m.; conductivity, 45–170 reciprocal megohms.

TABLE III

Association of Larvae in Three Selected Areas in Cheboygan County, Michigan

The figures represent the number of times a species was collected in the same pool with other species.

	Aedes aurifer	canadensis	cinereus	communis	diantaeus	excrucians	fitchii	flavescens	impiger	implacabilis	intrudens	lateralis	pullatus	punctor	spenceri	sticticus	stimulans	trichurus	vexans	Anopheles maculipennis	punctipennis	Culex apicalis	pipiens	restuans	salinarius	Theobaldia impatiens	inornata	morsitans
Aedes aurifer	..	1	..	..	..	..	1	..	..	1	..	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..
canadensis	1	..	21	11	10	21	2	1	1	13	3	8	1	22	2	..	2	6	..	1	..	4	..	..	..	..	..	12
cinereus	..	21	..	8	4	12	1	1	1	5	1	5	1	13	1	..	3	5	..	..	..	2	..	..	..	..	..	10
communis	..	11	8	..	6	9	..	..	2	3	4	8	..	12	..	..	5	7	1	..	..	1	..	..	..	..	..	5
diantaeus	..	10	4	6	..	9	..	..	..	6	4	2	..	7	..	..	1	3	1	..	..	..	..	..	..	..	..	3
excrucians	..	21	12	9	9	..	2	1	..	9	3	6	..	13	1	..	1	5	1	..	..	..	..	..	..	..	..	7
fitchii	1	2	1	..	..	2	..	1	..	2	..	1	1	2	1	..	1	..	..	..	..	..	..	..	..	..	..	..
flavescens	..	1	1	..	..	1	1	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
impiger	..	1	1	2	..	..	..	..	..	..	..	1	..	2	..	..	2	1	..	..	..	1	..	..	..	..	..	1
implacabilis	1	13	5	3	6	9	2	..	..	..	2	3	1	13	1	..	..	2	1	..	..	..	..	..	..	..	..	1
intrudens	..	3	1	4	4	3	..	..	..	2	..	2	..	2	..	..	2	3	..	..	..	..	..	..	..	..	..	..
lateralis	..	8	5	8	2	6	1	1	1	3	2	..	..	6	..	..	2	3	..	..	..	..	..	..	..	..	..	1
pullatus	1	1	1	..	..	..	1	..	..	1	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..
punctor	1	22	13	12	7	13	2	..	2	13	2	6	1	..	1	1	1	5	2	..	..	3	..	..	..	..	..	13
spenceri	1	2	1	..	..	1	1	..	..	1	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
sticticus	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	1
stimulans	..	2	3	5	1	1	1	1	2	..	2	2	..	1	..	..	..	4	..	..	..	1	..	..	..	..	..	1
trichurus	..	6	5	7	3	5	..	..	1	2	3	3	..	5	..	..	4	..	..	..	..	..	..	..	..	..	..	2
vexans	..	..	..	1	1	1	..	..	..	1	..	..	..	2	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Anopheles maculipennis	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	6	..	..	..	1	1	..
punctipennis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	3	..	..	..	..	..	..
Culex apicalis	..	4	2	1	..	..	..	..	1	..	..	..	..	3	..	..	1	..	..	6	3	..	1	6	2	1	1	8
pipiens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	1	1	..
restuans	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	1	..	..	1	1	2
salinarius	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..
Theobaldia impatiens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	1	..	..	..	..
inornata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	1	..	..	..	..
morsitans	..	12	10	5	3	7	..	..	1	..	..	1	..	13	..	1	1	2	1	..	..	8	..	2	..	..	..	..

Genus *Wyeomyia* Theobald

One species of the genus *Wyeomyia* occurs in the region.

35. *W. smithii* (Coquillett). — Common in bog areas; adults emerge throughout spring and summer; larvae occur continuously in pitchers of *Sarracenia purpurea*. Analyses not made of the water in these plants.

ANALYSIS OF SPECIES LIST

Six genera and 35 species of the family Culicidae, subfamily Culicinae, were collected in these areas. The species are distributed among the genera as follows: *Aedes*, 23; *Anopheles*, 3; *Culex*, 4; *Mansonia*, 1; *Theobaldia*, 3; and *Wyeomyia*, 1. Six of the 8 genera and 35 of the 45 species native to the state occur here. Since 75 per cent of the genera and about 80 per cent of the species reported for the state were taken in the three areas it seems that the waters in them, when conditions are favorable, are well adapted to mosquito production.

At times *Uranotaenia sapphirina* Osten Sacken was abundant in adjacent bog situations, and *Culex tarsalis* Coquillett and *Theobaldia incidens* Thomson were taken near by, but not from these areas. Adults of *Mansonia perturbans* occurred commonly throughout the areas, but no larvae were collected. It seems possible that at times these four species might also be produced in the areas studied.

LARVAL ASSOCIATION

Table III shows the association of larvae as found in the three areas studied. The figures represent the number of times a species was collected in the same pool with the other species.

SUMMARY

1. A list of the species of mosquitoes found in the three areas studied is presented. Six genera and thirty-five species of Culicidae, subfamily Culicinae, were collected.

2. Data are given showing the larval association in the three areas.

3. Contrary to previous taxonomic descriptions, many adult specimens of *Aedes intrudens* lack lower mesepimeral bristles, and numerous larvae of *Culex apicalis* show a variation of 1–2 head hairs per trichopore.

4. The variational ranges of the principal chemical features of the waters in which larval specimens of each species (some exceptions) grew are presented.

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THE BREEDING HABITS OF THE RIVER CHUB, *NOCOMIS MICROPOGON* (COPE) *

JACOB REIGHARD †

CONTENTS

* Contribution from the Department of Zoölogy, University of Michigan.

† EDITOR'S NOTE — Professor Reighard died on February 13, 1942, and hence did not have opportunity to see the proof of this paper. The proof was read by Dr. Karl F. Lagler, of the University of Michigan, who did considerable work on the manuscript while Professor Reighard was still alive. Professors Peter Okkelberg and Carl L. Hubbs, both of the University of Michigan, read the manuscript and offered suggestions.

In Professor Reighard's death the Michigan Academy has lost one of its most esteemed members. The idea of organizing a state scientific society was conceived by him early in the nineties, while he was head of the Department of Animal Morphology of the University of Michigan. He served as president of the Academy in 1900.

INTRODUCTION

THESE studies on the breeding habits of the river chub were made in Mill Creek, a tributary of the Huron River, Washtenaw County, Michigan. The part of the stream in which the observations were conducted lies in the NW ¼ of Section 18, Scio Township. Here the creek, 2 to 4 rods wide, meanders for half a mile in a northerly direction. In this stretch is a series of three rapids, in which the shallow water runs swiftly and somewhat brokenly over large stones and small boulders. As the channel broadens and deepens downstream toward each rapids the current slackens into a deep pool of relatively still water. Between two successive rapids the water-sorted bottom material grades from large stones upstream to fine gravel and sand downstream, just above the next rapids. From near the break of the lower rapids to a distance of 6 to 8 rods above it the bottom, to some depth, is made up mostly of stones, 2 to 4 inches across, embedded in fine sand and gravel. The creek bed here is fairly smooth, as though paved with the larger stones, and is uniformly covered with slimy brown algae. A few small boulders, a foot or two in diameter, are scattered about this area. The water in this pool is 18 to 24 inches deep, and its surface is nearly smooth. It is on such bottom that the nests are found in Mill Creek. In 1904 and again in 1926 I counted nine nests within a distance of 190 paces; in 1905, eight; in 1915, four. A total of thirty nests were studied in this habitat.

Nest building takes place from mid-April to the end of May, with water temperatures ranging from 15 to 20.5° C. I have watched the construction of nests on various dates from April 20 to May 28 in 1904, 1905, 1915, and 1926.

METHODS OF FIELD OBSERVATION

In making observations I would approach the stream slowly and cautiously with the sun at my back. Visibility was best when the sun was shining and where a screen of heavy foliage on the opposite bank kept the direct light of the sky from reflecting from the water's surface. In the early work a stop was ordinarily made at a distance of 30 to 40 feet to look for nests, with the aid of field glasses. In their initial stages river-chub nests are shallow pits 9 to 12 inches across, and lighter in color than the undisturbed bottom about

them. Later they become conical heaps of stones ranging in size, according to the stage of completion, from low mounds a few inches high and 12 to 15 inches in diameter to tall mounds 10 to 12 inches above the general bottom level and having a diameter of 3 to 4 feet. Such stone piles are locally characteristic only of *Nocomis* and are unmistakable.

Cautious approach was often rewarded by a sight of the fish at work. If they were not present a motionless wait would bring them back to their tasks. These waits often ran from five minutes to half an hour, but a longer wait was usually fruitless. After the fish had been busy for a while I often crept nearer on hands and knees and again stopped for a time, with my head lifted only high enough to enable me to see the nest. So by several stages I advanced stealthily until I was on the edge of the bank, and the fish were little, if at all, disturbed. I avoided all quick movements of hand or head, and did not permit my garments to flutter in the wind. After a time on the bank I often moved toward the nest slowly, with frequent stops, until I stood over it. A water glass (glass-bottomed container) that was sometimes used for closer observation did not disturb the fish for more than a few minutes. It is in this manner that one makes his first approach to a nest, but later approaches, it was found, could be more rapid.

On my first visit to a certain nest it took me half an hour, including stops, to reach it without disturbing the fish. After an absence of an hour and a half I went to the nest without stopping. The fish left, but returned in ten minutes. On my third approach, on the following day, I again walked directly to the nest. Once more the fish left, but it resumed work in four or five minutes. The nesting fish thus accommodates himself very quickly to the observer, who thereafter becomes almost an integral part of the normal landscape of the fish. The fish became adjusted to a group of people much as to an individual; I often brought ten or twelve students to the bank to observe them.

In order to insure accuracy of data it was necessary to gain an acquaintance with the field characters not only of the two sexes of the species primarily under observation, but of all associated fishes as well. To this end collections were made simultaneously in other sections of the same stream and the characters of the various species were learned. To illustrate the kinds and the utility of such in-

dices to species in these studies characters used to distinguish the river chub and associated species are given. The large breeding males of *N. micropogon* are often seven to ten inches in length overall, robust, and with coarse scales as seen in the water. The border of the opercle is dusky, but not black like that in the common shiner (*Notropis cornutus*). No black spot occurs on the dorsal, but there is one in the horned dace (*Semotilus a. atromaculatus*). The front borders of the pelvics and the anal are dead white, being whiter than those in the common shiner. The sides above the lateral line and the lower body surfaces are rosy in the larger males. A band of sharp conical pearl organs runs across the front of the head. In the larger males the area of integument that bears the nuptial tubercles is elevated into a hump, so that in side view the fish seems to have a Roman nose. A dark spot at the caudal base, which is sometimes indistinct, is not round, although it is in the hornyhead, *Nocomis biguttatus*. Young males with tuberculate heads have a well-marked lateral stripe from snout to caudal and are without the rosy color of sides and belly. All these field characters are easily visible as one stands at the side of the nest, and most of them may be seen at a considerable distance with field glasses. They serve to discriminate the river chub, *N. micropogon*, from its somewhat smaller relative, the hornyhead, *N. biguttatus*, with which it might otherwise be confused,[1] especially since the breeding behavior of the two species is much the same.

The females are usually one third to one half the length of the largest males. They are without pearl organs and do not have the rosy belly seen in active males. Along the side of the head and body they have a well-marked dark stripe not found in full-grown males. Their anals and pelvics are bordered in front with white, as they are in the males. The abdomens of those seen about the nest are usually plainly distended with eggs.

It should be noted that the color differences that I have given here are for freshly caught specimens, since death and preservation alter some of these characteristics.

[1] Hubbs (1926) has given descriptions and photographs of the males of the two northern species of *Nocomis*, both of which had previously passed as "*Hybopsis kentuckiensis*," and Hubbs and Lagler (1941) have published photographs of both sexes of *N. biguttatus* and of a male *N. micropogon*.

OBSERVATIONS ON NESTING

Nest Building

I use the word "nest" for that definite, limited area of construction on which or over which the eggs are laid or into which they are deposited. In some species it may be merely a small area of the bottom swept clean by the fish or hollowed out to make a depression; in other species, those of *Nocomis*, for example, it may be a more elaborate construction. The following account of nest building by the river chub is based on the observation of 24 males engaged in the process over a total period of about 42 hours. The individual observation periods ranged from 1 to 7 hours.

Location of the Nest Site

The breeding ground or general area on which the nests of *Nocomis micropogon* are built appear to be largely determined by the character of the bottom. It must afford enough stones of suitable size for nest building. In these areas the water is usually 18 to 24 inches deep (occasionally as deep as 36 inches), and the current is not sufficiently strong to impede seriously the activities of the fish.

Within any one locality favorable for nesting the sites chosen come to lie in groups of two to four. The distances between the nests of such a group range from 1 to 8 rods, with the average approximately 4 rods. Only once have I found two nests side by side and close together. The nearest nests of adjacent groups that are separated by rapids may be 15 rods apart.

I have never seen a male engaged in digging a pit or carrying stones to his pile except when ripe females were near enough to show themselves occasionally. An adjacent quiet portion of the pool or a still water under an overhanging bank, where females may lie, probably plays some part in fixing the nest location within the breeding ground. The suitability of the bottom seems also to be of importance in determining the precise location. The bottom must be loose enough for the pit to be dug to a depth of four to six inches without encountering stones that cannot be moved, and other nests must not be too close.

Only once have I seen a river chub engaged in the selection of a pit site. A large male left a half-completed nest, went upstream a short distance, and tested the bottom here and there by seizing

the projecting stones in his mouth and trying to move them. He presently located a spot, some feet above his former workings, where the bottom had not been disturbed and began to move a few stones out of it. Soon, however, he swam two or three feet farther upstream, again testing the bottom in various places until he reached a small white patch of bottom from which a few stones had already been removed. Here he remained for fifteen minutes, carrying out stones. Then he went back to the immediately previous excavation and removed more stones from it. After twenty minutes he returned to his original nest and carried stones to it, but three or four minutes later was again at the second of the little pits he had dug and put some stones into it. Apparently, then, suitable spots for pit digging are discovered by trial, and the final nest site is selected after several tests.

Digging the Pit

When the male has located a spot from which stones can be readily removed he starts to dig the pit. He seizes any projecting part of a stone that he can get into his mouth, at times jerking it from side to side to loosen it, and then turns partly on one side, lifts the stone, and swims away with it protruding from his mouth. If a stone is too large to be readily dislodged by lifting, the fish may put his opened mouth against it and slide it along the bottom. When a stone has been lifted it may be moved directly out from the pit, to either side, and dropped either at the edge or within some twelve to eighteen inches of it. If the stone is carried to a greater distance, it is transported downstream with the aid of the current and deposited. Nearly all the stones that are removed from the pit are dropped within two somewhat gourd-shaped areas that are in contact with the pit site at their narrower upper ends and grow wider toward their diverging lower ends, which lie two or three feet below. In one nest the upper ends began six inches above the pit. These areas I call "the dumps." On them nearly all the excavated material is deposited.

Only the exposed surfaces of the superficial layer of undisturbed stones on the bottom are dark-colored (on account of the covering of ooze or algae). Their other surfaces and all faces of the underlying stones are clean, and are colored according to the kind of rock. As soon, therefore, as the surface layer of dark stones has been removed

in digging, the pit becomes conspicuous by reason of the contrast of its color with that of the surrounding bottom. The dumps too become well defined and easily recognized by their light color, since the deeper-lying clean stones from the pit are scattered about.

Some of the stones carried to the dump are three to four inches wide, from which size they grade down to small ones one-quarter inch across. They lie intermingled, unsorted, and scattered at random over both dump areas. Several pebbles may be deposited outside them, directly above the pit, and still others below it, between the lower parts of the pit dumps, but they are too scattered and too small to obscure the outlines of the dumps.

The stones that the male removes from the nest may be twice as large as its head and hence may project prominently from its mouth during transportation, but occasionally when it seems to be carrying nothing at all it may spit out sand or gravel. During this act its head is lowered, the mouth is opened, and finally the contents are suddenly discharged. Sand thus spit out is swept downstream, making a small cloud as it goes. There is usually so little of it at the site chosen that it does not form a noticeable deposit below the pit, as it does during the nesting of the horned dace.

The completed pit is a roughly circular, somewhat saucer-shaped excavation, 12 to 15 inches in diameter and 3 to 6 inches deep at its center.

The Stone Pile

For the sake of clearness I continue to describe the nest building as though it were carried through without interruption. But interruptions there are, due to storms, to rapid changes of the water temperature, to the coming of females that do or do not spawn, and to the presence on the nest of other males of *Nocomis* and of individuals of both sexes of several other species of fish that either use it as a spawning place or feed on the eggs. All these happenings, to be described in detail, delay the work and greatly complicate the picture.

Although the movements of females about a male engaged in the construction of a nest may interrupt his work, their advent upon the scene produces certain typical changes in the pace and character of the nest-building activities. Furthermore, while digging the pit the male leaves it from time to time for no apparent cause unless it be to search for hidden females. He goes out of sight

downstream and then, in a minute or two, returns to his work. During his absence and occasionally at other times females enter the pit singly or in groups of five or six. The returning male chases them away; I have never seen them spawn in the pit. The presence of females in and about the pit seemingly speeds the work of digging. The fish seems to work faster under the stimulus of seeing the nest nearing completion.

With the pit more or less completed and with females present the stone-carrying activity of the male is reversed; he begins to bring stones back into it.

Once a male busily engaged in carrying stones from his pit gradually became less active in this work until after 20 minutes he took out only an occasional stone. During this period he had begun to bring stones from distances as great as 8 feet *upstream* and to drop them into the pit or just above it. The activity of carrying out, which at first alternated with that of carrying in, became the less frequent. Finally, in 6½ minutes 24 stones were brought to the pit and none taken out. A little later 18 were brought in within 4 minutes. Another male, after steadily removing stones from his nearly completed pit for 10 minutes, reversed his activities and began to carry nest material in. The first few stones brought in were at once picked up and taken out, but only slightly beyond the excavation. After five minutes of vacillation between carrying them in and carrying them out it steadily brought them in without removing any. Females were seen about both these pits, and they entered one of them. Two other males transported stones both in and out during a 10-minute period, but they were not observed long enough to see whether complete reversal was effected or whether females were present. The coming of females to the pit appears most likely to be the stimulus for the reversal of the stone transportation, for it was repeatedly noted that as the stone pile grew the carrying-in activity was temporarily reversed in the absence of females.

Having once turned completely to filling the pit and building a pile, the male continues the work more or less steadily. Whereas in digging his pit he carries the excavated materials downstream and to either side and deposits them within well-defined dump areas, in accumulating materials for his stone pile he most often goes upstream and brings the stones down to the growing pile, for that is the easier way.

Usually in nest building a male swims up eight feet, or less, and in his workings covers a fan-shaped area above the pit site. Some stones, however, are brought in from downstream, and in time all the larger ones that have been deposited on the dumps are re-gathered. Wherever he goes, he seizes the projecting parts of stones in his mouth and jerks his head sidewise five or six times in order to dislodge them if they are stuck. If he cannot loosen a stone, he goes to another, and so on until he finds one that he can detach. Then he returns with it protruding from his mouth and drops it into the pit or on the pile. The sizes and kinds of material selected and the methods of transport are as previously described for the methods of excavation, except that little if any sand is brought back. He may return with a valve of a large mussel or with two valves that are still held together by the ligament, or with entire living mussels. A six-inch-long cannon bone of a sheep was added to one nest. Whatever can be tugged loose from the bottom and carried is brought in.

Working in this way the male gradually constructs a pile where he had earlier dug a pit. The stones brought in are often covered with brown ooze on one side, and they usually fall with that side up, so that they may soon conceal the brightly colored stones of the pit bottom. In 55 minutes one male carried in enough stones to cover the pit bottom completely, and at the end of 1 hour and 25 minutes the pit was level-full. In 2 hours and 25 minutes the stones were heaped 2 inches above the plane of the stream bottom. By the following day this male had accumulated enough stones to make a domelike pile 30 inches across and with a maximum height of about 3 inches above the bottom of the creek. Two days later the pile had grown to a diameter of 33 inches and a height estimated to be 6 inches. By this time the male had gone, and the nest was apparently completed; the stones for the heap had been brought together in about 2½ days. The plan of a typical nest and the calculated amount of work involved in its construction are given later in this paper. A nest of a river chub and its construction by the male have been very briefly mentioned by Greeley (1929).

From time to time while the male is building his pile ripe females approach. The male then often stops his building activities, lowers his head very rapidly, and excavates a shallow spawning trough about the width of his body and about one half to two thirds his

length. He does this by tossing or carrying stones from some place on the pile. The long axis of this minor excavation coincides with the current, and it is deeper at its upstream end. I have seen three such trenches made in ninety minutes by the same male. While hollowing out this little trough he stops at short intervals and lies over it with his head slightly elevated and pointed upstream; he then spreads his pectorals and for a fraction of a second rapidly vibrates the part of the body in the region of the vent, thereby rubbing his vent over the stones. This tremor may aid in cleaning the groove or may be an act of self-excitation preliminary to spawning. While the trough is being made or when it is completed a female usually enters and lies in it to spawn, as subsequently described. Spawning completed, the male returns with increased activity to his stone carrying and drops stones into the trough so rapidly that it is soon obliterated. It is filled the more quickly because most of the stones for the purpose are brought only from short distances — from the edge of the nest or from points near it. While filling the trough, especially just after dropping a stone into it, the male may lie in it and, with his vent close to the bottom, may repeat the trembling movement just described. If a female does not enter the trough the male remains near it or lies in it for a time and then slowly resumes the carrying-in of stones and brings them from greater distances. Thus in the course of building his stone pile he digs many spawning troughs and fills them after the eggs have been laid. Even as the male reverses his carrying activity from out to in on completion of the pit, so he changes it many times from in to out and back to in as he digs spawning trenches and fills them with stones. Often several unused depressions are found on the top of a completed and abandoned nest. Although most of them seem to be troughs for which no females were available for spawning, some may be the work of the central stoneroller (*Campostoma anomalum pullum*), which has been observed using the same stone pile.

Behavior of Females during Nest Building

As the males are engaged in nest building the females apparently lie in a shelter downstream from the nest, and are seen only when they approach it from below. This they do either while the male is still carrying stones out of the nearly completed pit or while he is bringing them in to fill it or to build the pile. During the time the

pit is being dug the male may leave it for a short time. Then the half-dozen females that are poised below it may enter it together or one at a time. A female repeatedly picked up a small pebble from the pit, carried it four or five inches beyond the edge, and then returned and dropped it into the middle of the pit. On another occasion several females in company picked up small stones at the pit's edge, carried them out three or four inches, and dropped them. When the male returns he drives away any females that may be in the pit.

After the pit is filled and while the male is away a female may come to it and carry out small stones so that she may dig a little spawning trough. A six-inch female made a trough equal to her own length, three inches wide, and one inch deep. An excavating female may seize many of the small stones brought in by the carrying male and take them out as soon as they are dropped. By thrusts of her head she may repeatedly drive away any other female that approaches. Before being ejected the intruder usually has time to burrow with her head into the pebbles, as though searching for eggs; she then seizes a small pebble and rushes away with it. Four or five females that came to one unguarded nest put their heads down together and burrowed for an instant with vigorous tail lashings, and then rushed away at the approach of the male or an excavating female.

The Completed Nest

A nest on which no fish had worked for three days and which was of typical size and shape (as determined by previous observations) was selected for the following detailed analysis of a completed structure. It was a roughly dome-shaped pile of surface stones lightly covered with algae and fine organic material. The stones lay where they had been dropped or where they had been moved during the excavation of spawning troughs, and gave no evidence that their irregular surfaces had been smoothed by the fish.[2]

[2] Though most completed nests are rough-surfaced, I have seen one with a surface somewhat like that of a rather smooth undulating pavement. The stones composing it seemed to have been often shifted and pressed down, so that they had become fitted together, mosaic-like. Since many stonerollers and common shiners had worked on this nest the smoothing was probably due to the activity of those species rather than to that of the river chub; the nests or spawning troughs of the central stoneroller often have a similar mosaic-like surface.

While I was lifting the stones by the handful off this nest in order to measure them, much black silt and organic matter was washed out from among the stones as well as from them. The top of the pile was a rather level spindle-shaped area that measured five by eight inches and had its long axis at right angles to the stream. From this elevated plateau convex slopes, of nearly uniform curvature, extended to a border that did not deviate from a smooth curve more than two or three inches at any point. There were three depressions, apparently unused spawning troughs, on the slope; two were symmetrically placed a little more than halfway down on the downstream side, and one was at the middle of the upstream curvature.

Linear Measurements of the Nest[3]

The measurements of this nest follow (those with an asterisk beside them are vertical distances downward from the water's surface):

	Inches
1. Stone pile:	
To middle of top	6.5 *
To stream bottom just above upper edge	16.5 *
To bottom just below lower edge	13.0 *
To middle of right side	14.0 *
To middle of left side	13.0 *
Average distance, water surface to nest edge	14 +
Maximum height of stone pile above plane of stream bottom	7.5
Greatest diameter with current	49.0
Greatest diameter across current	37.0
Average diameter	43.0
2. Pit, after being emptied:	
Greatest diameter with current	13.0
Greatest diameter across current	15.0
Average diameter	14.0
Depth at center	4.0

Volume of Nest Materials

The shape of the stone pile made it difficult to calculate its volume from its dimensions. The problem was solved by removing the materials in three- and twelve-quart containers, which were emptied in a single pile on a level spot on the shore. The final appearance and dimensions of this heap were essentially those of the undisturbed nest. After removal of the pile the pit was emptied

[3] Measurements of nests of *Nocomis biguttatus* are given by Hankinson (1932, p. 414).

and the contents were measured. The emptied pit, which was under the center of the pile, had nearly vertical walls. It looked as it did when first completely excavated by the fish.

The measured volume of the nest materials was found to be as follows:

Stone pile, exclusive of material in pit	66.0 quarts
Pit contents	4.5 quarts
Total volume of nest material	70.5 quarts

The largest stone from the pile measured 1.5 by 3.25 inches on the flat surface and was 0.5 to 2.5 inches thick. Others nearly as large were thicker and thus probably bulkier. An apparently average stone was 1.0 inch by 1.25 inches by 1.0 inch.

In order to estimate the total number of stones in the pit and in the pile the three-quart measure was filled with stones taken here and there at random. This random sample contained 100 stones to the quart. Thus it was estimated that a total of 7,050 stones composed the pile and the pit. In addition, there were 35 valves of mussel shells, 2 complete shells, and 5 living mussels; most valves ranged from 0.5 to 2.75 inches long, but one reached a length of 4.25 inches.

Labor Involved in Building the Nest

In transporting a stone to the nest a fish often travels an estimated 12 feet each way and sometimes 20 feet, that is, 24 to 40 feet for the round trip. If we conservatively estimate an average distance of 12 feet for the round trip, we have probably made sufficient allowance for the relatively few trips on which two or more small stones are brought back. At 12 feet per trip the fish would have traveled 84,600 feet, or a little over 16 miles, to accumulate his stone pile. If we assume the nest material to have the weight of broken stone, roughly 100 pounds per cubic foot, their total weight in air would be 235 pounds. Deducting the weight of an equal volume of water (147 pounds — the water displaced would be less than the volume of broken stone), we find the weight in water of the materials brought in to be 88 pounds. If this weight is lifted and carried in 6,000 trips, the average weight per trip is a little over one fifth of an ounce. All the labor of moving this material, together with that of the original excavation, is usually accomplished by a single male.

Time Taken to Build the Nest

It was on June 4, 1926, that I removed the nest described in the preceding section; I left it at 5 : 00 P.M., with the pit empty. When I revisited it at 11 : 00 A.M., June 5, the pit had been refilled, and on one side of it stones were piled a little above and beyond its margin. The water temperature was 15° C. Eighteen hours had elapsed, during about eight of which there was full darkness, and the night had been cold and clear, probably near frost.

I have a fairly complete direct record of the time taken by one male to fill his pit and complete his stone pile:

April 28, 2 : 45 P.M. Male that has been carrying stones out from his pit begins to carry them in. His pit is circular and measures 12 inches across and 3 to 5 inches deep.
3 : 45 P.M. Light-colored pit bottom nearly covered by darker stones brought in by the male.
4 : 00 P.M. All stones of pit bottom covered by dark stones
4 : 10 P.M. Pit level-full.
5 : 00 P.M. Stones heaped 2 inches above pit.
April 29, 10 : 00 A.M. Stone pile 30 inches across and 2 to 3 inches high.
May 1, 2 : 00 P.M. Stone pile 33 inches across and 6 inches high. Stones from 2.5 to 3 inches and down to 0.25 inch across.

The time taken to fill this pit was from 2 : 45 P.M. to 4 : 10 P.M., or 1 hour and 25 minutes. Hence the time that then elapsed until the observation that the pile was completed, at 2 : 00 P.M., May 1, was roughly 69 hours, but three nights were included and possibly no work was done during the early morning period of low temperatures. Probably less than half the 69 hours were spent on the work. The time required to fill the excavation as recorded above was 85 minutes. The pit of the measured nest contained 4.5 quarts of material and the pile 66 quarts. If we assume the 4.5 quarts to have been gathered in 85 minutes, the construction of the pile would have taken, at the same rate, $\frac{66}{4.5} \times 85$, or 1,247 minutes (20.8 hours) of continuous work. The total time for digging the pit and accumulating materials for the pile would then be 20.8 hours plus 1 hour and 25 minutes or, roughly, 22 hours for the measured nest. The two results, less than one half of 69 hours and 22 hours, indicate that between 20 and 30 hours of continuous work was all that was needed to accumulate the stones in the nest.

Rate of Carrying Stones

In the refilling of the pit, as described above, more than 450 stones were brought in, perhaps 600, since the pit was overfilled. By leaving the number at 450 we make allowance for the carrying of more than one stone on some trips. If this required 85 minutes, as it did in the nest in which the filling time was observed, the average time per trip is about 11.3 seconds.

If the 7,050 stones of the measured nest were gathered in 30 hours of continuous work, we may suppose that only about 6,000 trips were required, since more than one stone is sometimes carried at once. Eighteen seconds would then be the average time of a trip. In the filling of the pit that was accomplished in 85 minutes, with an assumed 450 trips, the average duration of a trip was 11.3 seconds, or, on the assumption of 300 trips, 17 seconds.

These rough calculations were verified by actual observation of the rate of carrying. In midafternoon, when the water is warmest and fish are most active, I have counted 18 carrying trips made in four minutes, at an average rate of 13.3 seconds per trip; also in midafternoon, 24 trips in 6.15 minutes, an average rate of 15.6 seconds; again in midafternoon, 9 trips of 1 to 8 feet (2 to 16 feet for the round trip) in three minutes, an average rate of 20 seconds per trip; still again, 9 trips in 105 seconds, at an average rate of 11.6 seconds per trip. These observed rates agree fairly well with the 11.3- to 18-second rate calculated from nest measurements and from the elapsed time of building the measured nest, and they show that the average rate of carrying stones is between 10 and 20 seconds per round trip. Taken together, these data again indicate that between 20 and 30 hours of continuous work is required to fill a pit and to build the stone pile of a nest.

The foregoing results hold for fair-weather conditions. The effect of unfavorable weather on the building rate is shown by the following observations made in 1926:

May 18. Pit found 8 inches square and apparently 3 to 5 inches deep; no male on it.

May 19–24. Weather cold and raining. Nest not observed.

May 24. Pit now larger and oval; estimated size, 8 to 10 inches. Male carrying out.

May 25. Pit level-full and stones piled perhaps an inch above its edges, at 12 : 00 M.

May 26. Overcast and cold; nest not observed.
May 27. Water 14° C. in morning, rising to 16° C. at 1:00 P.M. Stone pile apparently about doubled in bulk since the 25th. Not yet of full size.
May 29. Male still at work on the nest.
May 31. Showers.
June 1. No change in the nest; no work in progress on it. Apparently complete.
June 2–3. Cold and windy; nest not visited.
June 4. Nest unchanged.

On account of unfavorable weather between 11 and 14 days were taken to finish this nest and to fill the pit and build the stone pile.

SPAWNING

As already noted (p. 405), the presence of females in or near the nest at any time after the pit has been filled, or nearly filled, results in the male digging a spawning trough. From time to time while thus engaged and just after dropping a stone the male may interrupt his work and lie in the trough for a short time with his head upstream. Thus placed, he spreads his pectorals and rapidly vibrates the body for a fraction of a second so as to rub his vent over the stones.

Thereupon a female may enter and lie at his side, with her long axis oblique to his. He then bends his body, so that his head is turned slightly toward her. His lateral tubercles are thus pressed against her as he crowds her against the side of the trough. While he is pressing against her she may, by swimming forward, escape quickly without spawning. This maneuver may be repeated several times without actual spawning. With or without such preliminary mating activities the female, having entered the trench, may lie belly down on its bottom while the male enters. After entry, the male may turn partly on the side and bend his body slightly with its convex side toward her and the ventrolateral angle pressed against her. She then rises from the bottom, and as she does so the male throws his body to one side and catches her between the body on one side and the upper surface of the spread tuberculate pectoral fin and the lateral pearled surface of the head on the other side. Extrusion of the sex elements takes place at this time. This spawning act is about as rapid as closing and opening the hand. When released the female swims away downstream, no doubt to return again and again. Whether the fertilized eggs fall into the trench and are covered by the stones later brought in or are swept downstream I do not know. The spawning act somewhat resembles that of the horned dace

(*Semotilus atromaculatus*), as described by me (Reighard, 1910), and that of the common shiner (*Notropis cornutus*), as often observed by me and as reported in detail by Raney (1940). The act for the river chub, however, is more deliberate and is preceded by the female lying on the bottom in the spawning trench, whereas in the two other forms the female does not take this preliminary position, but is poised above the bottom when the male first encircles her.

GENERAL BEHAVIOR OF THE MALE

Long observation of the breeding activities of a species of fish under natural conditions reveals much behavior that is no essential part of these activities. The observer comes to think of each species of fish as having, like each race of man, certain general behavior characteristics and a certain type of disposition.

The male river chub is relatively slow in all his movements. He is unhurried in his work of excavation and in the transportation of stones. He moves deliberately, as though he carefully considers each act before executing it. Even the spawning embrace seems slow as compared with that of other cyprinids. In the presence of females, however, he becomes somewhat brisker while digging the spawning trench and while filling it. But at no time does he seem to work with the speed of other breeding minnows of similar habits.

While the male is building his nest a horde of fifty to two hundred fish may intrude at one time, to spawn on it or to seek eggs to eat. He does not try to eject them so consistently as do other minnows. He often moves undisturbed back and forth through the throng. The associated species give way little or much according to the size of the river chub, but only long enough to let him pass. Usually he behaves as though they were not there. The incessant struggles between breeding males, common in some minnows, do not appear to take place between males of *N. micropogon*. Very rarely does an individual thrust with his tuberculate head at another male of his kind or at large males of the common shiner or stoneroller. The large size of his stone pile makes it difficult or impossible for him to keep it free from intruders, and he does not try to do so.[4]

[4] Recording observations made by himself and Hubbs, Hankinson (1932, p. 418) indicated that *Nocomis biguttatus* in general follows the same behavior on its nest, but that the associated spawning males of *Notropis cornutus* busily drive off intruding fish — perhaps in a commensal relation.

I have seen no evidence that there is any gradual process of accommodation by the male to the presence of the regularly associated species or to occasional visitors on his nest; rather they are accepted at once. So familiar also are floating leaves or patches of foam and their shadows that they bring no reaction from the male as they cross the nest. Even a meandering softshell turtle produced only a momentary flurry. All these things are parts of the normal environment. The breeding *N. micropogon* accommodates himself rapidly to the presence of the observer, as already noted (p. 399), though behavior in this respect shows individual differences. When the observer approaches a nest, causing the fishes to leave it, the male may return in four minutes or not for twenty minutes. The variations in the time of return are probably due to a combination of the physiological state of the fish, the immediate force of the sexual urge, and the strength or the nature of the disturbing stimulus that caused him to flee. As I stood beside one nest the male swam toward my rubber boots as though to examine them and then turned and disappeared downstream, but came back almost immediately. Two or three minutes later he repeated this maneuver, but did not return for about a minute and a half. I then cautiously moved a step nearer. He approached me for the third time, then dropped only a little way downstream and at once retraced his course. He paid no further attention to me; he had become fully adjusted to my presence.

When a nest is approached on which there are fishes other than *Nocomis* all may leave. The other species usually return before the river chub; males of the common shiner consistently return sooner. Once when I had approached within eight feet of a nest the *Nocomis* left and did not return for ten minutes, although three large males of the common shiner remained on the nest along with a great number of females of that species and with many males and females of *N. rubellus*. It was twenty minutes before this male began once more to carry stones into the nest, and it was forty minutes before he worked actively and regularly. Meantime the shiners were undisturbed. Again, when I came within ten feet of a nest on which there was a male *Nocomis*, along with six large breeding male stonerollers, the river chub left, whereas the other fish were undisturbed. The males of *Campostoma* and *N. cornutus* are more brightly colored and more active than those of *Nocomis*, and are constantly fighting

and parading, but they accustom themselves more rapidly to an observer. Males of *Nocomis*, more subdued in coloration and less agile, are less aggressive and slower in their accommodation to a watcher. In their movements, color changes, reaction to associated species, and adaptation to the observer they are also found to be relatively slow.

NEST ASSOCIATES

Accessory Males of Nocomis

I have stated that each nest is usually built by a single male. As seen in the field, males differ in size of body, in coloration, in the size of the hump on the head, and sometimes in the details of distribution of the pearl organs on the head, but the last character is visible only to an observer who stands directly over the nest. Without tagging or marking there are no accurate means of distinguishing males of the same size so that they may be recognized from day to day. During several hours of uninterrupted work at a nest one may keep track of a single male and thus be sure that he always has the same fish under observation. When observations cover several days, the progressive accommodation of the male to the observer, together with size, coloration, and indefinable general appearance, affords fair assurance that the same fish is being studied from day to day.

Sometimes one accessory male, rarely two, may work on the nest at the same time with the principal builder, and we need to know how much of the work they do. In such circumstances there is never any difficulty in telling the males apart. In eight of fifteen periods when eleven nests were observed for a total of twenty-six hours only one male was present. In five of the remaining periods one accessory male was present and working part of the time, whereas during two of these periods sometimes one and sometimes two accessories were near by. The supernumerary males were usually smaller than the builder — in one observation they were only half as long — but their tuberculate heads indicated that they were mature. One accessory male was nearly as long as the builder, and another was longer.

In the seven observation periods during which accessory males were present my records show the amount of work done by them to be as follows: (1) in one period the single and smaller accessory did about as much carrying in during seven hours as did the larger

builder; (2) in another period the builder carried stones *to* the nest steadily during two hours, while one, and at times two, accessories carried stones *out* intermittently and so partly neutralized his work; (3) during three periods the single accessory did very little work and in two others he did none. On the whole, we may say that in these seven periods the accessory males present contributed very little to the building of the nest and that during a total of fifteen observation periods the construction work of accessory males was negligible. I have never seen one of them engage in the spawning act. Each nest may thus be regarded as the work of a single male; the *Nocomis* eggs laid there may also be regarded as having been fertilized by a single fish.

Other Species

In addition to harboring mature and immature males and females of *Nocomis* the large pile of loose stones forming the nest studied attracted three other species of minnows.[5] It is an excellent breeding place for many of them, and when the river chub is not on his nest the others use it. Other species that have been observed taking advantage of the stone piles are:

Campostoma anomalum pullum, central stoneroller. — Breeding males are often from six to eight inches long, strongly tuberculate, brightly colored, and very active. As many as six males, usually ranged side by side, may be present at one time, busily digging their spawning troughs in the stone pile, fighting together, and spawning with incoming females.

Notropis cornutus, common shiner. — Breeding males often are six to eight inches long and are also strongly tuberculate, brightly colored, and very active. From one to twenty large males may be poised over the stone pile, fighting continuously, carrying an occasional small pebble at random but without digging spawning trenches, spawning, parading upstream in pairs, and then returning to the nest.

Notropis rubellus, rosyface shiner. — Breeding males, nearly three inches long and bright red on head and back, may often be seen, by an observer standing over the nest, pairing with females and spawning.

[5] Hankinson (1932, p. 415) listed similar spawning associates of *Nocomis biguttatus* in the Saline River, Michigan.

Half of the thirty nests studied for a short time had one or more additional species of fish on it. The other half were unoccupied. Most of them were completed and, apparently, abandoned. In Table I are shown the frequencies with which each species occurred alone or in association with other species on nests under construction.

TABLE I

SPECIES OF FISH SEEN ON *NOCOMIS MICROPOGON* NESTS DURING FIFTEEN OBSERVATION PERIODS

Group number	*Species present*	*Times observed*
1.	*N. micropogon*	1
2.	*C. a. pullum* and *N. cornutus*	1
3.	*N. micropogon* and *N. cornutus*	1
4.	*C. a. pullum* and *N. cornutus*	2
5.	*N. micropogon, C. a. pullum,* and *N. cornutus*	3
6.	*N. micropogon, N. cornutus,* and *N. rubellus*	5
7.	*N. micropogon, C. a. pullum, N. cornutus,* and *N. rubellus*	2
	Total number of nests observed	30
	Number of nests on which fish were present	15
	Number of periods with *N. micropogon* present	14
	Number of periods with *C. a. pullum* present	8
	Number of periods with *N. cornutus* present	12
	Number of periods with *N. rubellus* present	7

In one period of 7 hours no fish other than *N. micropogon* was seen, whereas in the 13 remaining periods *N. micropogon* was present together with one or more of the three associated species (Table I). The river chub was present, alone or with other species, during 14 of 15 periods; *C. a. pullum,* during 8; *N. cornutus,* during 12; and *N. rubellus,* during 7. The last species has never been seen on a nest except in association with *N. cornutus* (five times) or with *N. cornutus* and *C. a. pullum* (twice).

The chub was absent during only one brief observation period on an uncompleted nest. Longer observation would probably have revealed *N. micropogon* on the nest, for when an observer approaches a nest in such a manner as to disturb the fish, either the chub leaves while the associates remain or all leave and the associates return before the nest owner does. In the absence of *N. micropogon* the nest is taken over by associates. It is likely that a chub had recently left one nest found to be occupied by associates, that it was in the neighborhood, and that it would have been seen again had the ob-

servation period been longer. It appears, then, that it is the presence of the working river chub that attracts associates to the nest rather than the nest itself. On one occasion a chub that left its unfinished stone pile to dig two pits near by was followed from its nest to the new locations by all the many associated shiners. The associates go where a builder is at work. There they find not only a suitable spawning place, but probably food in the form of eggs or of materials dislodged by the moving of stones. The behavior of the chub apparently governs their reactions.

When only one to three individuals of *N. cornutus* or only one to three of *C. a. pullum* are on the nest on which *N. micropogon* is at work the picture is simple. The males of *N. cornutus* usually occupy the upstream slope of the stone pile well above the nest surface; their females approach from downstream, singly or a few together, and go to the males one at a time to spawn. A little "knot" of waiting females, much smaller than the males, may gather and keep position in mid-water a little downstream from the males. Among them may be females of the river chub. The stonerollers are usually to be found on the downstream side of the nest, on or near the bottom; their females come to them in similar fashion and may form waiting groups down current, among which may be females of *N. micropogon.* When both the common shiner and the stoneroller are present the picture becomes more complicated. The males of the former, sometimes twenty together, are over the upstream slope of the pile; the latter, as many as six together, are on the downstream slope. Behind these males, and in part over the stoneroller males, is a cloud of many intermingled hovering females of both species and of female river chubs. They form a fan-shaped mass above the lower nest slope, with the point of the fan upstream. The poised females move up and down, so that at a little distance the mass seen edgewise suggests a slowly waving pennant. Immature males of all three species may be included in the mass. So it was in six out of fifteen of my observation periods on associated species.

The situation becomes still more complicated when *N. rubellus* is present along with *N. cornutus,* as it was in five observation periods out of fifteen. The bright red males and the females of this three-inch minnow are then in part intermingled with the swarm of dull-colored females of *N. cornutus* and the few females of *N. micropogon.* Some rosyfaces hover below the others, nearer the nest top, and mostly

extend downstream beyond the other species, a little above the bottom and below the stone pile. Many of the *N. rubellus* individuals thus form a border or fringe to the fan-shaped cloud of mixed females.

In only two of the fifteen periods did I see all three associated species (male stonerollers, several male common shiners, and many rosyface shiners) on the nest together. My field notes do not indicate that the scene was then greatly different from that afforded by the combination of common and rosyface shiners. The maximum number of fish on the nest could only be estimated, not counted. I have seen as many as twenty to thirty adult males of the common shiners and stonerollers and behind them very many females of these two species together, with females of the river chub and immature males of both species, and intermingled with these a great horde of *Notropis rubellus*. The aggregation may have numbered two hundred.

Besides the associated species of minnows on nearly all nests there are other occasional visitors. Once I observed a single hognose sucker (*Hypentelium nigricans*) rooting in the nest in the absence of the male river chub, and twice again I saw this sucker near the nest.[6] It probably feeds on the eggs.

Here I add from my field notes some excerpts recording the occurrence of other species on the *Nocomis* nest.

May 4, 1905: On the upstream edge of the nest are poised some half-dozen large males of *Notropis cornutus*, and below these hang many small males and females of the same species, perhaps twenty-five in all. Along with them are four or five females of *Nocomis* and many bright-red *Notropis rubellus* about three inches long. Through this crowd the smaller of the two river chubs working on the nest comes with his stones and drops them on the upstream, slightly concave, face of the pile. He pays no heed to the common shiners as he passes through the throng, although they give way a little. Sometimes he seems to be unable to reach his destination through the obstructing throng, but backs out and comes to it from a different angle. There seem to be here at one time twenty to thirty individuals of *N. cornutus* and as many of *N. rubellus*. The larger *Nocomis* is given a much wider berth by the other fish than the smaller one, and usually none but the very large *Notropis cornutus* come into contact with him. These he repels with lateral thrusts of the head.

[6] Hankinson (1932, pp. 418–419) reported seeing a male of *Nocomis biguttatus* attack an intruding *Hypentelium*, driving it off.

May 4, 1905: A large *Nocomis* is carrying the stones and occasionally stops to excavate a spawning trough and lie over it. For the most part the nest is occupied by a large number of males of *Notropis cornutus*. One of these is especially large and generally holds the nest against the others, of which there are twenty or thirty. In his absence several somewhat smaller males of equal size take his place. Behind these hover twenty or thirty smaller males and females. There are also two or three stonerollers at work over the nest and a great swarm of *N. rubellus* is present. When nothing else is distinguishable their color can be seen at quite a distance like streaks of red sunlight over the nest. *N. cornutus* is spawning.

May 28, 1905: The stone pile was twelve inches across and three high when I began observing it today. It contains the usual assemblage of *Notropis cornutus* and *N. rubellus*, together with a single large "bald-headed" *Nocomis* and a few females of *Nocomis*. While the *Nocomis* is carrying stones the common shiners crowd over the nest and spawning trench and spawn. Several times after the male *Nocomis* has left the spawning trench about twelve brilliant rainbow darters, *Poecilichthys c. caeruleus*, enter the trench and work head down among the pebbles as though seeking eggs. A soft-shelled turtle, *Amyda s. spinifera*, about six inches long comes from below and, clawing away the nest pebbles with his forefeet, inserts his snout among them and apparently feeds on eggs. At least I can see his jaws move. The shiners and at first the *Nocomis* avoid his head and take position behind him and at his side. Now the *Nocomis* resumes his stone carrying and is soon dropping stones on the nest as usual. Some of them fall on the top of the half-buried head of the turtle. The turtle traverses about one third the diameter of the nest, then suddenly raises his head, apparently sees me, comes to the surface, sticks his head out within four feet of my face, blows out air, then turns and swims downstream.

Hybridization of Associates on the Nocomis Nest

It is obvious that with males and females of three or four species of minnows on the nest top engaged in spawning in large numbers at the same time, there is opportunity for hybridization to take place. The diagram (Fig. 1) shows the usual position of these species on the nest at the time of spawning.

Eggs and milt are extruded during the spawning embrace, which

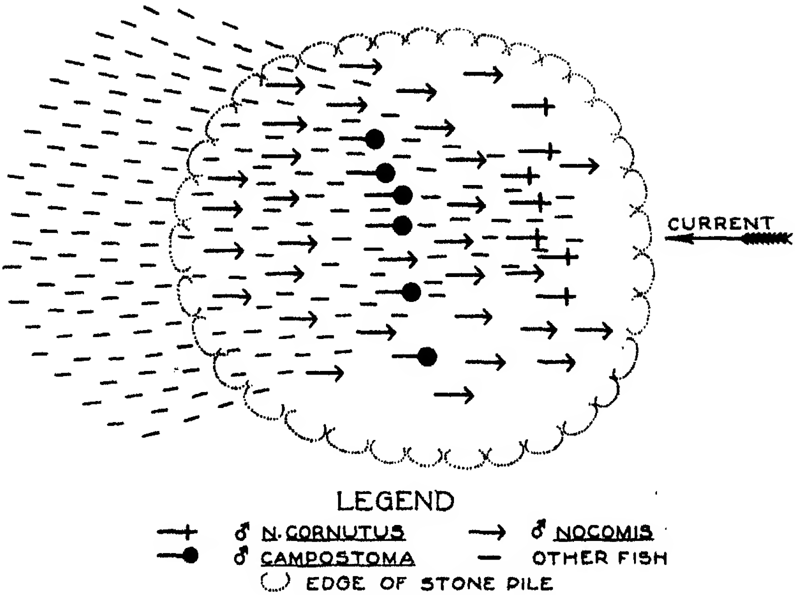

FIG. 1. Diagram showing the usual spawning locus of fishes breeding on the stone-pile nest of the river chub. "Other fish" refers to ripe females and immature males and females of *Nocomis*, *N. cornutus*, and *Campostoma*, and ripe males and females of *N. rubellus*

takes a fraction of a second. The eggs, enveloped in a cloud of milt, are immediately fertilized. The excess milt is swept downstream except as it may be retained for a time in the pockets of stiller water of a spawning trough. If one of these species so placed on the stone pile that its sperm may be carried downstream spawns at a time when the sperm can reach the eggs of another species just as they are extruded, accidental hybridization is possible. The diagram (Fig. 1) shows the usual position on the nest of the breeding males of the three larger species and of males and females of *Notropis rubellus*. Ripe females of all four and males of *N. rubellus* are included in the fan-shaped swarm of small fish below the middle of the nest, from which individual females of the three larger species move up to their males from time to time. There are six possible species crosses and twelve theoretical possibilities if reciprocals are taken into account. *N. cornutus* usually occupies the upstream position, and its sperm

may reach eggs of the other three species. *Nocomis* males may be anywhere on the nest, but are unlikely to be upstream from spawning *N. cornutus.* Their milt may reach eggs of two of the other three species, possibly of all three. *N. rubellus* males, on account of their position, probably will not produce hybrids, but female *rubellus* may cross with males of all the three other species. Females of *N. cornutus*, spawning at the upper side of the nest, presumably may cross only with male *Nocomis.* Of the twelve reciprocal crosses theoretically possible under these circumstances eight are thus possible and four improbable (Table II).

TABLE II

Possible and Improbable Reciprocal Crosses among Fishes Breeding on River Chub Nests

Males	Females			
	Nocomis micropogon	*Notropis cornutus*	*Notropis rubellus*	*Campostoma anomalum pullum*
Nocomis micropogon	...	Yes	Yes	Yes
Notropis cornutus	Yes	...	Yes	Yes
Notropis rubellus	No	No	...	No
Campostoma anomalum pullum ...	Yes	No	Yes	...

SUMMARY

Nests of *Nocomis micropogon* are located in streams in eighteen to twenty-four inches of water, on bottom that affords stones of suitable size for nest building and where the current is not sufficiently strong to impede the activities of the fish.

The nest is constructed by the male, which first digs a pit in the bottom by moving out stones and then fills the pit and builds a pile of stones that, when completed, is rather large.

The principal dimensions and contents of a completed nest pile are: maximum height above plane of stream bottom, 7.5 inches; average diameter, 43.0 inches; volume of materials in pile and underlying pit, 70.5 quarts; number of stones in pit and pile, 7,050.

Work involved in accumulating a stone pile is considerable;

an approximate total of sixteen miles is traveled in about 6,000 trips to and from the nest; weight in water of materials that are transported to build the pile is 88 pounds.

The equivalent of twenty to thirty hours of continuous work by one male is required to build a complete nest; actually this working time may be spread over four days or longer.

Spawning takes place repeatedly on one nest in small troughs excavated on its surface; in the spawning act the sex elements are extruded when the male curves his body over that of the female and holds her for an instant with the side of his head and the pectoral fin, both of which bear nuptial tubercles.

Struggles between breeding males of the river chub rarely occur; neither does the river chub consistently drive other fishes from his nest, as do some other minnows.

Among the nest associates of the river chub are accessory males of the same species that contribute but a negligible amount of work to the construction of the nest.

Breeding associates of the male river chub are mature and immature males and females of the same species, stonerollers, and common and rosyface shiners.

Possibilities of hybridization between breeding associates of the river chub are shown to be either favored or rendered improbable by the positions that they customarily assume about the stone pile.

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ORIGIN OF DIVERSE STRAINS OF AN APHID SPECIES WITHIN A LIMITED AREA *

A. FRANKLIN SHULL

A STRAIN of aphids of the species *Macrosiphum solanifolii* collected in Ann Arbor in the year 1923 was shown to react to light in its developmental processes in such a way that most individuals possessed wings if their late prenatal stages were passed in intermittent light of certain periodicities, but were wingless if those stages were subjected to continuous light. In 1929 that strain experienced a radical change in its behavior, so that thereafter more winged individuals were produced in continuous light than in intermittent, but the difference was not so great. It also produced, after this change, many more intermediate-winged individuals than before (Shull, 1932). This strain was kept nearly ten years longer, during which time its behavior underwent no further material change.

To replace this strain for experimental work another clone was collected in 1931, and found to respond to light precisely as did the 1923 strain at first. It was used incidentally as demonstration material in a genetics class and in January, 1939, unexpectedly produced somewhat more winged offspring in continuous than in intermittent light. The experimental work being done on that strain for some time prior to 1939 had been directed toward other ends, so that the class results were the first indication that the 1931 strain was changing as had its predecessor.

Since a sharp difference in response was essential in the experiments, new strains were collected by Miss Winifred White in the summer of 1939, all of them within a few miles of Ann Arbor. To avoid possible confusion of these aphids with other letter-designated strains that have been so recorded in the literature, these new strains

* Contribution from the Department of Zoölogy, University of Michigan.

may be named M, N, O, P, and Q. They were tested under identical conditions in the fall of that year, and some of them proved to be very different from others. After a period of adjustment to laboratory conditions adult wingless aphids of each strain were reared in intermittent light and in continuous light, and the nature of their offspring noted. The results of these tests are given in the accompanying table.

TABLE I

THE NUMBER OF WINGED AND WINGLESS OFFSPRING PRODUCED BY WINGLESS APHIDS OF FIVE DIFFERENT STRAINS WHEN REARED IN CONTINUOUS AND IN INTERMITTENT LIGHT (8 HOURS OF LIGHT, 16 HOURS OF DARKNESS)

Strain	Parents in continuous light			Parents in intermittent light		
	Offspring			Offspring		
	Wingless	Winged	Percentage winged	Wingless	Winged	Percentage winged
M	325	0	0	2	318	99.4
N	285	224	44.0	280	49*	14.2
O	471	0	0	172	242	58.5
P	308	0	0	3	340	99.1
Q	514	0	0	199	397	66.6

* In addition, sixteen offspring had intermediate wings.

Two of the five strains (M and P) reacted in the manner desired for experiments. Two produced more winged offspring in intermittent than in continuous light, but the difference was not a sharp one. One actually produced more winged offspring in continuous light than in intermittent, just as did the 1923 strain after its remarkable reorganization in 1929, and as did the 1931 strain in January, 1939. It is possible that only three strains are here represented. M and P could belong to the same clone, though they were collected at places twelve miles apart. O and Q, in view of the number of offspring obtained, could differ as much as they do and still be parts of the same clone, though they were collected five or six miles apart. N is certainly different from the others, but was collected near M. The uniqueness of N is further attested by its production of intermediate-winged individuals.

The existence of diverse strains in one locality raises the ques-

tion how they originated. There are four conceivable methods: (1) each one may have descended from a fertilized egg which lived over the preceding winter, and may owe its difference from other strains to genetic recombination; (2) they may have hibernated in the parthenogenetic phase from unlike strains of the preceding warm season; (3) they may have become different by different mutations from one or more other strains, just as modifications have been observed to occur in the laboratory; or (4) they may have immigrated, already different, from southern latitudes where the parthenogenetic form could overwinter. There are few facts which would definitely indicate a choice among these possibilities with respect to this particular species in the vicinity of Ann Arbor, but certain data bear on the probability of each of them.

GENETIC RECOMBINATION

Genetic recombination in fertilized eggs which existed no farther back than the preceding winter is opposed by the low hatchability of these eggs. In the laboratory, in some experiments with crosses between the red and the green color varieties (Shull, 1925), only a few eggs among the thousands obtained ever hatched. It appears to have been the experience of others who have worked with the fertilized eggs of this species that few of them hatch. Many fertilized eggs were subjected to the rigor of winter, partly indoors and artificial, partly natural, without any increase in the number hatching. It is possible that dietary requirements for hatching are met in nature but not in laboratories. Thus the final autumn generations in nature are supposed to live on rose vines, whereas in laboratory experiments they have mostly been fed the year round on their so-called summer host, the potato. If one or more components of the fertility of mammals are dependent on certain vitamins, it is conceivable that the ability of fertilized aphid eggs to hatch might depend on whether the winged female which laid them fed on the potato or the rose. No one appears to have tested this possibility. If the hatchability is as low in nature as it is in the laboratory, it might seem unlikely that five randomly collected aphids would belong to at least three different strains. A judgment on this point would have to rest on knowledge of the number of fertilized eggs produced, and no data of this sort for southern Michigan are available.

HIBERNATION IN PARTHENOGENETIC PHASE

The overwintering of parthenogenetic aphids would merely push the origin of differences among them back to an earlier date. Such hibernation would, however, permit the strains to be more than one year old (from the fertilized egg), and the age of the strain may have some relation to mutational changes. The two strains in which a change in the response to light (in wing production) was demonstrated had each been reared parthenogenetically for six or seven years before the modification was observed. This fact could be interpreted to mean that an age effect is involved. It also could mean merely that, among the aphids whose response to light mutated, it took a long time for any to be chosen for breeding. Each experiment involved only six or eight females among available hundreds, and random selection of these few breeding individuals could accidentally avoid the mutants for a long time. The chief argument for an age effect is that the age of the two strains was so nearly the same (six or seven years) when the change in response occurred.

Whether this species, *M. solanifolii*, could overwinter in the parthenogenetic phase is questionable. Winter in southern Michigan nearly always involves temperatures as low as −15° to −20° C. one or more times in the season. Some parthenogenetic aphids are known to hibernate in regions having such extremes of temperature at the places where thermometers are kept, but they are mostly root-feeding species, and the temperatures to which they are actually subjected are probably less extreme. There are, however, some indications that species other than root feeders can endure such low temperatures if they are not too prolonged and especially if the cold spells are separated by frequent periods warm enough for some normal activity. On the whole, it seems unlikely that *M. solanifolii* could hibernate out of doors in this region in anything but the fertilized egg stage.

There is the further possibility that the winter is passed, not in outdoor hibernation, but in greenhouses. The parthenogenetic female of this species has a very strong preference for the potato and the rose. Indeed, it is difficult in the laboratory to induce it to stay long on any other plant; starvation seems usually to be preferred to a change of food. In greenhouses, potatoes are seldom available, but some kinds of roses are usually present. Inspection of the green-

houses in or near Ann Arbor has never revealed any of them. These searches have been very careful ones, for aphids were badly wanted when they were made. However, greenhouses in smaller localities where fumigation is less thorough or less frequent might harbor this species. The evidence available seems rather against this form of overwintering, at least in this locality, but is not conclusive.

MUTATION

Origin of differences between strains by means of mutations is obviously suggested by the demonstrated occurrence of such changes in two strains, as reported in this and earlier papers. Presumably mutation in nature is as likely as mutation in confinement, unless some essential condition is not met under natural circumstances. If, for example, mutation cannot happen until the clone is a number of years old, and if all aphids in a northern locality belong to clones which originated not earlier than the preceding spring, it would plainly be impossible for the differences between strains in such an area to arise through mutation.

It should be pointed out that the mutations which have occurred in the laboratory *may* have been environmentally produced, or that environment may at least have contributed to their production. The mutation of 1929 was detected immediately after a series of attempts to eliminate gamic females by means of heat, during which temperatures as high as 31° C. had been applied for long periods. The mutation discovered in January, 1939, occurred in a group of aphids whose ancestors had long been reared at 24° C., though no such change had taken place in a branch of the same clone which was being reared at 14° C. Experiments now in progress are designed to show whether heat may have been responsible for the changes.

The frequency with which mutations can be discovered in these parthenogenetic lines is presumably greatly reduced by the fact that the parthenogenetic eggs are diploid. There is no reduction division in maturation, and no regular recombination of genes. A mutation could hardly occur at a given locus in more than one chromosome of a pair of homologues; hence a recessive mutation would not be detected. Dominant mutations would be discoverable at once, but some sort of chromosomal reorganization would be needed to reveal a recessive mutation.

Mutations in aphids could occur in the mycetome cells, rather

than in the eggs, but presumably only dominant ones would be discovered. Nothing is yet known concerning a possible function of the mycetome in this respect.

IMMIGRATION FROM WARMER REGIONS

It is well known that aphids are carried by wind. It is mostly the winged forms that can be so transported, but in them it is very probable that air currents are more effective than their own active efforts. Winged females appear, in the species under consideration, in any generation after the stem mother, in varying proportions which depend on light, temperature, parentage, and genetic constitution. Winds in the north temperate zone come frequently from the southwest; hence there is every opportunity for aphids to be carried northward, perhaps as rapidly as the season and plant growth advance.

In warm climates these aphids pass the winter in the parthenogenetic phase. It is not necessary to go farther south than Virginia to find *M. solanifolii* more or less active at any time in the winter. Indeed, it has been reported from certain localities that the gamic forms are unknown. A rather moderate migration would suffice to populate the Michigan area with clones which overwintered in the parthenogenetic form farther south. It is conceivable that fertilized eggs might be wholly unnecessary for repopulation each season.

Facts which would help one to form a correct judgment concerning the significance of such migration are mostly lacking. Statistical aid would come from a knowledge of the frequency of physiologically different strains, but the collection and testing of the five clones reported in this paper are the nearest approach to such a census. To know how large an area is covered by a single clone would be helpful, but no information on this point is available. Nothing else is known which would indicate the size of a population unit in these aphids.

One fact seems to stand against immigration from the south, at least as the sole source of the summer population, namely, the occurrence of the pink variety of *M. solanifolii* on the same rose vine in Ann Arbor in three successive years. The vine died at the end of that period, so that the test could be no more extensive. No other rose bush in a number of neighboring blocks in the city bore the pink variety, and many of them not even the more common green variety. It is difficult to believe that random immigration from the

south could each year have planted the pink variety on that particular bush. The alternative supposition, however, is not much more easily accepted. Fertilized eggs of a pink strain, if one assumes with some risk (Shull, 1925) that they would give rise to pink aphids, would presumably have to be deposited on or near that bush each fall. Since the parthenogenetic aphids did not ordinarily remain on this rose all summer, the gamic forms of that or some other pink strain would have had to return to this particular bush. The homing instinct of migrating birds is puzzling enough, without attributing such capacities to still lower orders of life. A further alternative explanation would be to suppose that the same lot of fertilized eggs continued to hatch over several years, but such longevity of fertilized eggs appears not to have been reported.

CONCLUSION

The conclusion appears to be warranted that fertilized eggs have not been abandoned as one of the means of propagation of this species, and that recombination of genes is therefore one of the sources of clonal diversity. Mutation must probably be added to this as a species-wide source of variability. With respect to the population in any limited area immigration from other regions, particularly from the south, should probably be regarded as a more potent factor of variation than it has usually been considered.

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GEOGRAPHY

THE FRONTIER OF NEW ENGLAND IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES AND ITS SIGNIFICANCE IN AMERICAN HISTORY

STANLEY D. DODGE

IN DISCUSSIONS of the development of the frontier of settlement in the United States Miss Semple and others have tacitly assumed that the Appalachian Mountains were a serious barrier to the westward movement of the pioneers.[1] The facts upon which this assumption has been made are that from such centers of settlement as Philadelphia the pioneers spread to the base of the first high Appalachian ridges in the course of fifty years after the first arrival of Europeans, and that then, for from fifty to a hundred years, the outer edge of the area of European settlement lay in the Appalachian Mountains. Throughout this period the valleys of the Ohio and its tributaries came more and more under the control of the French operating from their bases at Montreal and Quebec.

The northeastern end of the frontier of settlement in the United States was in New England. An examination of the position of the frontier there will make a better interpretation of the importance of the Appalachians possible, in the first place, because the mountains of New England are not so difficult to traverse as are those farther south, and, in the second place, because the frontier of settlement never lay for any long period in either the Green Mountains or the White Mountains. Only the southern continuation of the Green Mountains in the Berkshire Hills of western Massachusetts acted in any way as a barrier to the progress of settlement.

Let us examine the facts of the settlement of New England. The accompanying map (Fig. 1) shows by its isochrons the dates of settlement of the various sections of the New England states. It is based on the recorded settlement dates of some five or six hundred

[1] Semple, E. C., *American History and Its Geographic Conditions* (Boston, 1903), p. 36.

towns.[2] The settlement of New England started in a minor way about 1610, when agents of English companies began spending the winter as well as the summer on the coast of Maine, but the first real settlements were not made till Plymouth was settled in 1620, Cape Ann in 1623, and Salem about 1627.

In the period from 1630 to 1660 the frontier of settlement advanced rapidly in the southern part of New England. The Connecticut Valley was occupied in 1636 at Wethersfield, Hartford, and Windsor in Connecticut, and at Springfield in Massachusetts. New Haven and Providence were settled in 1636 likewise, and within a few years most of the coast from Boston southwestward to New York was settled and from Boston northeastward as far as the Penobscot River.

After 1660 the settlement was less rapid, with some exceptions. The position of the isochrons for the years just after 1660 shows that no progress was made in Maine,[3] and that there was delay in the advance of the frontier into the eastern upland of southern New England from the vicinity of Boston, and into the western upland from the Connecticut Valley.

The circumstances of this slowing of the advance of the frontier need examination. Three separate nations were contending for the fur trade of the Connecticut Valley. The Dutch at Hartford were soon ejected by the English, who, however, continued the struggle for the possession of the beaver areas. The French were the only formidable foe. From their bases on the St. Lawrence they, with their Indian allies, followed the highways provided by the three principal rivers of New England, the Connecticut, the Merrimac, and the Kennebec. Along these they attacked the frontier settlements. The bloody massacre at Deerfield occurred in 1675, that at Hatfield in 1677, and, in general, from 1670 on the frontier was a dangerous place in which to live. Forts and blockhouses were of little avail; the English were driven back from the most exposed points.

In Maine the French had established themselves at Norridgewock, and for nearly a hundred years they were successful in protecting themselves from all encroachments on the part of the English

[2] Local histories, John Hayward's *New England Gazetteer* (Boston, 1839), H. E. Mitchell, *The Madison Register, 1903* (Kents Hill, Maine, 1903), and other registers.

[3] Greene, Francis Byron, *History of Boothbay, Southport, and Boothbay Harbor, Maine, 1623–1905* . . . (Portland, 1906), pp. 85, 96.

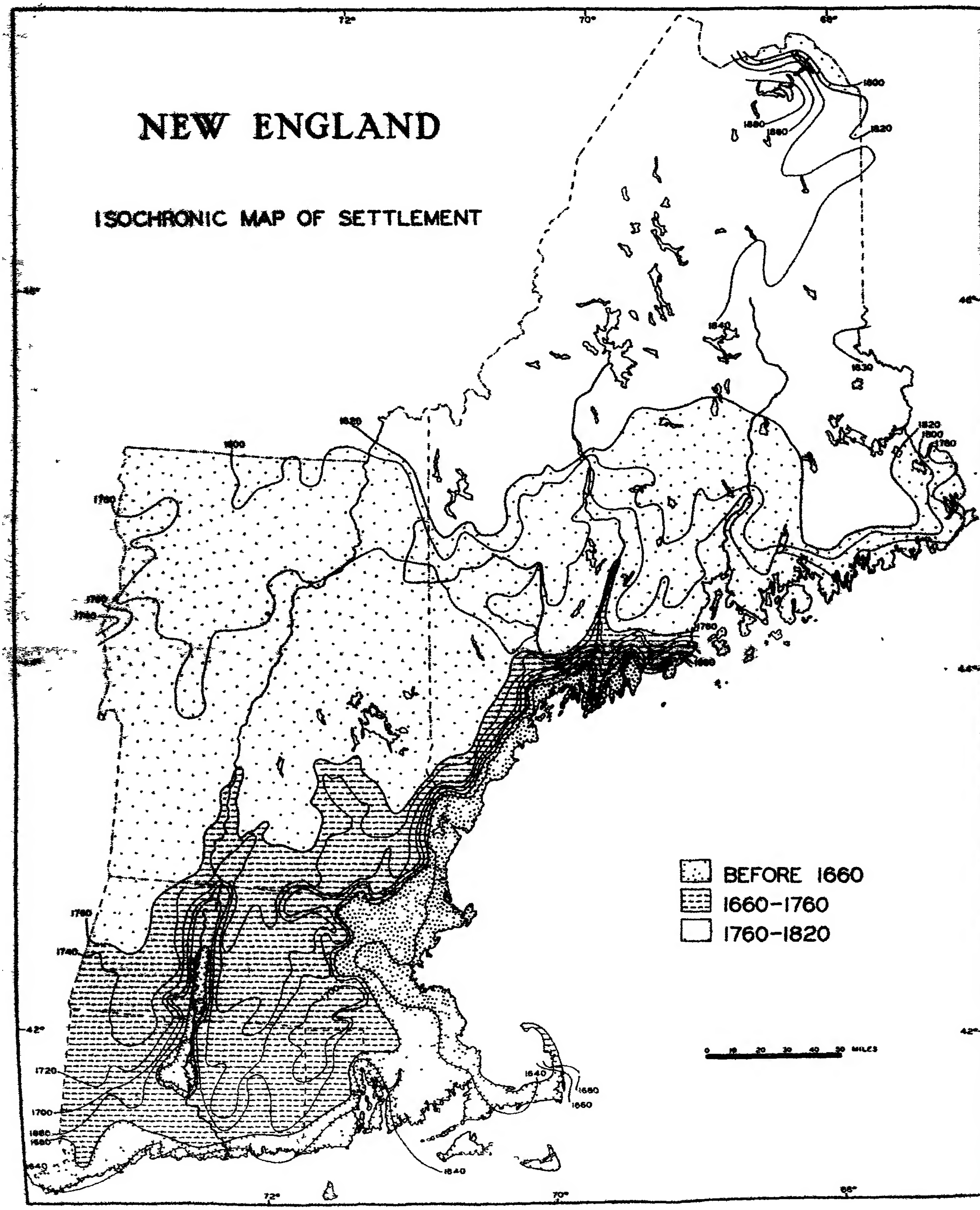

NEW ENGLAND
ISOCHRONIC MAP OF SETTLEMENT
BEFORE 1660
1660-1760
1760-1820
MILES

FIG. 1

along the Kennebec River, which was the principal highway to the interior of the province. East of the Penobscot the French controlled almost all the coast as well as all the interior.

It was in Maine alone, in the period from 1660 to 1760, that the frontier failed to be advanced at all. Elsewhere by the end of the period settlements had been made up the Connecticut as far as Charlestown, New Hampshire, and up the Merrimac beyond Concord. Toward the end of the period there was a fort up the Kennebec in Maine — Fort Western on the site of Augusta.

At other places settlement was only delayed, not halted entirely, as it was in Maine. It was delayed at the eastern edges of the eastern and western uplands in Massachusetts and Connecticut. In Maine, however, no significant topographic feature may be discerned in the zone in which the frontier rested in the period in which it was stationary.

The short period in which progress of settlement was delayed in southern New England may be explained sufficiently by the fact that the eastern upland was settled largely from the west, and by the consequent fact that the concentration of isochrons on the map in a position coinciding with that of the eastern edge of the eastern upland is merely incidental to the mechanical requirements of cartography. The delay thus indicated needs no explanation, therefore, since it was more apparent than real. In the western upland of Connecticut a similar illusion occurs largely because that area was settled from the south by people moving inland from New Haven along the course of the Housatonic River.

In Maine the explanation involves the consideration of a greater number of factors, for there the failure of the frontier to advance was real and not a cartographical illusion. A solution to the problem may be found among the following points:

1. It was in Maine that the first serious difficulties with the Indians developed, owing to the kidnaping and removal to England of several of them by one of the early exploratory voyagers in 1607.[4]

2. It was in Maine that the French secured greater control by the establishment of posts like that at Norridgewock and those at Castine and Machias, east of the English settlements.[5]

[4] James Rosier's narrative in Charles Herbert Levermore, *Forerunners and Competitors of the Pilgrims and Puritans* (Brooklyn, New York, 1912).

[5] Mitchell, *op. cit.*, pp. 11–13.

3. It was in Maine that the frontier lay nearer the French base at Quebec, and it was there that the frontier was connected to the French base by the easy natural highway provided by the Kennebec and Chaudière rivers.

4. It was in Maine that the fur trade was ultimately of greater concern than it was farther south, for beaver appear to have frequented the rivers of this state in greater numbers than they did those of the other New England states, at least in the portions of them that were then accessible.[6]

5. It was in Maine that the interest of English merchants in the fur trade persisted, and it was to their advantage to prevent as much as possible any movement into the interior that would interfere with the continuance of a supply of beaver.[7]

We may summarize these five points in the single general statement that the frontier remained stationary in Maine for nearly a hundred years because the French were successful in preventing any encroachment of the English in the area that they considered to be rightfully theirs, and because it was to the interest of the English merchants that the forest of Maine remain a wilderness and the haunt of the beaver.

Which of the five points was really significant in the history of the frontier in New England is explained by events after 1760. In 1755 a concerted attack on the French control of North America was begun. The ill-fated Braddock sought to capture Fort Duquesne at the head of the Ohio River in 1755, and Forbes succeeded in taking it in 1757 and in establishing Fort Pitt in its place. Crown Point on Lake Champlain fell to Amherst and Fort Niagara at the mouth of the Niagara River to Sir William Johnson. In 1759 Quebec was taken. When the treaty of peace was signed in 1763 the French government relinquished control of Canada, in which the principal strongholds had fallen to the English. Almost immediately the dam

[6] Clayton, W. Woodford, *History of Cumberland County, Maine* (Philadelphia, 1880), p. 234.

[7] Hanson, John Wesley, *History of the Old Towns of Norridgewock and Canaan* . . . (Boston, 1849), p. 313. In colonial times the reservation of trees in the forest of Maine for the exclusive use of the Royal Navy probably also helped to keep the forest intact. See Joseph Williamson, "Brigadier-General Samuel Waldo," *Collections of the Maine Historical Society*, First Series, 9 (1887): 80; Francis Gould Butler, *A History of Farmington, Franklin County, Maine* . . . (Farmington, 1885), p. 19.

was broken that had held up the waters of English settlement. The English spread in the next forty years over as much territory in New England as they had been able to occupy in the preceding one hundred and forty. New Hampshire and Vermont, except for two small sections in the extreme north, were settled before 1800, and mostly before 1790. In Maine settlements were made up the Androscoggin, Kennebec, and Penobscot rivers almost to the latitude of the northern boundary of Vermont and New Hampshire.

To support the proposition that it was the French possession of the northern part of the northern states of New England that prevented any advance of the frontier in the period 1660 to 1760 we may adduce two facts. In the first place, once the French menace had been removed settlement advanced rapidly to the boundary of Canada. In the second place, there was no halting of the steady advance of the frontier in the areas less effectively controlled by the French in the southern parts of the uplands of Massachusetts and Connecticut, and for the United States as a whole there was no halting of the movement of people southward from Pennsylvania into the Piedmont of Virginia and North Carolina or into the valleys of the southern Appalachians in Virginia, North Carolina, and Tennessee.

In conclusion, it may be said, therefore, that probably throughout its length the Appalachian barrier was a barrier in appearance only, that it was incidental to a halting of the advance of the frontier of English settlements, and that, had the French not possessed the interior of the North American continent, the Appalachian barrier would not have held up the continuous advance of settlement across the United States.

University of Michigan

A NEW MAP ON THE SURFACE CONFIGURATION OF MEXICO

HARRY E. HOY

THE physiography of Middle America is complex. There is a surprising array of mountains, plateaus, and plains of various types occurring under diverse conditions of climate and natural vegetation.

The physiographic map of Mexico here presented (Fig. 1) is the first of two on the configuration of Middle America. It includes all of Mexico and the adjacent areas of the United States, Guatemala, Honduras, British Honduras, and Salvador. The second map, now being drawn, will include all of Central America, the West Indies, and the north-coast countries of South America.

The first step in the preparation of the map was the tracing of the National Geographic Society's map of Mexico, Central America, and the West Indies (scale 1 : 5,500,000). The tracing was enlarged by the photostatic process to 1 : 2,750,000. For the physiographic details the standard reference works on Middle America by Schuchert, Sorre, and Sanders were utilized. Even more valuable was the series of Mexican Air Navigation Maps, on a scale of 1 : 500,000, consulted in the office of Professor Preston E. James, of the University of Michigan, and the "Millionth Maps" of the American Geographical Society. It should be noted, however, that the degree of reliability of these two series varies, for some are made from detailed topographic surveys on a scale of 1 : 100,000 and others contain scant topographic data, compiled from various sources.

Ten physiographic regions are tentatively outlined in Figure 2:

1. Central Plateau, a vast tilted upland sloping from 8,600 feet south of Mexico, D.F., to 3,600 feet, where the plateau extends into Arizona and New Mexico. The region is characterized by block-faulted mountains and volcanoes and separated by basins of interior drainage. This physiographic division dominates the surface configuration of the country.

2. Sierra Madre Occidental and Associated Coastal Piedmont, forming the highest ranges in the country — moderately high when seen from the Central Plateau and very high and abrupt when viewed from the Pacific side. The Coastal Piedmont consists of alluvial fans and low block-faulted outliers of the main mountain system. There is no good counterpart in the United States.

3. Sierra Madre Oriental, a low system of ranges when viewed from the west, but a bold escarpment from the east. A series of upturned sedimentaries parallel the mountains on the east.

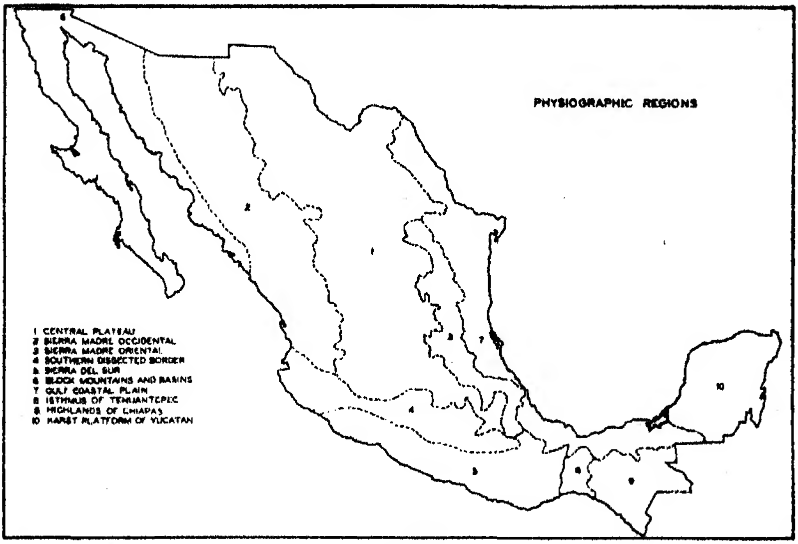


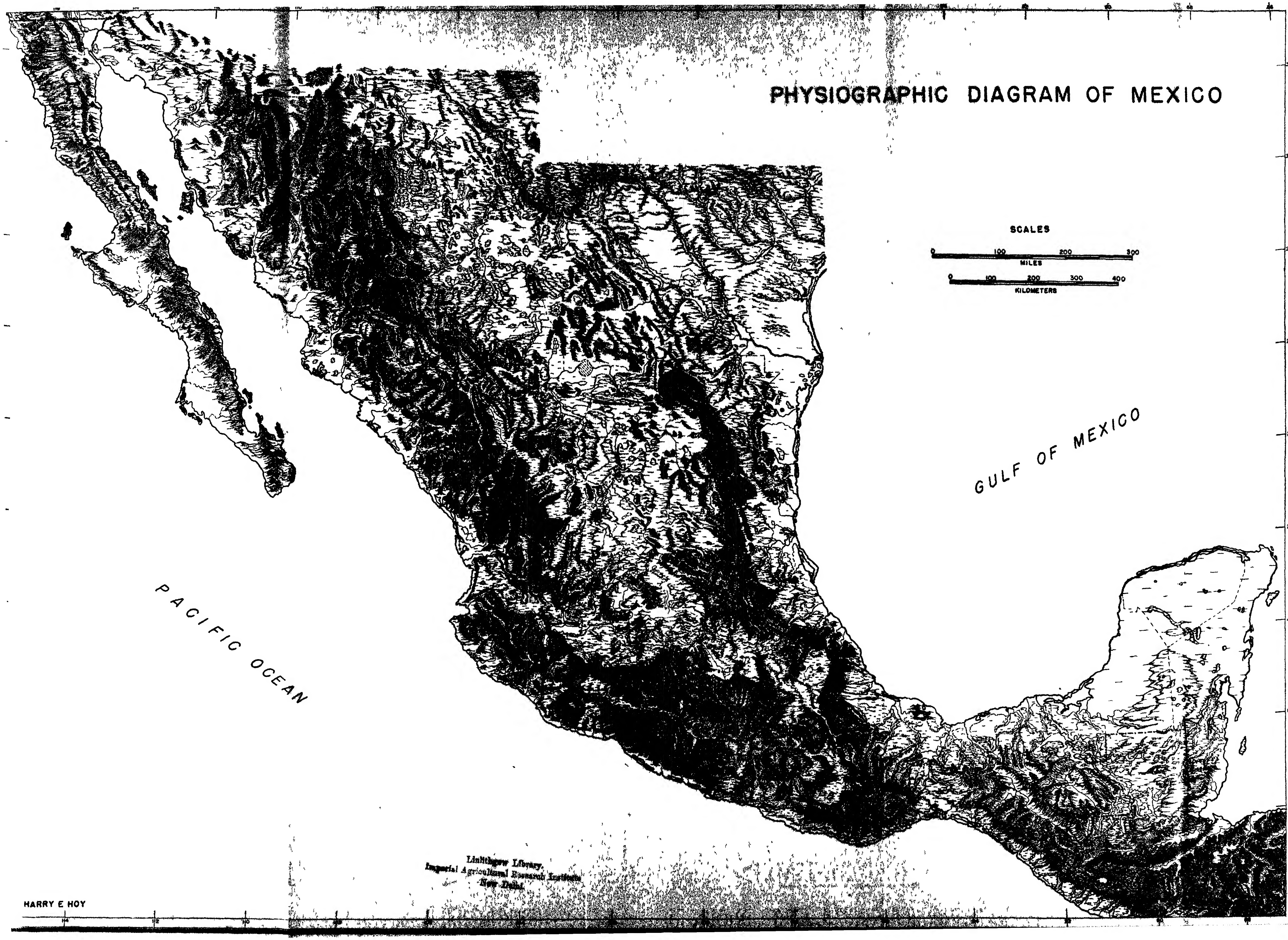
Fig. 2

4. Southern Dissected Border, so called for want of a better name, is the escarpment bordering the Central Plateau on the south. Structurally it is the northern flank of the Balsas Graben further emphasized by the series of giant volcanic cones along its crest. The more notable peaks are Pico de Colima, Nevado de Toluca, Popocatepetl, and Ixtaccihuatl.

5. Sierra Madre del Sur, a dissected plateau, south of the Balsas Graben. There is less dissection in the eastern part, where the more level uplands make up the Oaxaca Plateau.

6. Block Mountains and Basins of northwest Mexico, composed

PHYSIOGRAPHIC DIAGRAM OF MEXICO



of (1) the Sonora Desert, a mountain and bolson region like the Mohave of California, and (2) Lower California, a peninsula of block ranges and tablelands much like southern California.

7. Gulf Coastal Plain, a gently rolling sedimentary rock plain sloping toward the Gulf of Mexico. The surface is interrupted by occasional volcanic cones or plugs of volcanoes. The region is widest in the north, nearly pinches out to the south of Tampico, and widens to the south of Veracruz.

8. Isthmus of Tehuantepec, a low divide (300 feet) marking the structural break between North and Central America. Region 5 to the west stands much higher, as does the Chiapas Highland to the east.

9. Highlands of Chiapas, formed by the dissection of a plateau area. The highland of Guatemala and Honduras is an extension of this region into Central America.

10. Karst Platform of Yucatan, a low level plain interrupted by a few hills generally under 500 feet elevation. This region is characterized by collapsed limestone caverns known as "cenotes," and by the absence of surface streams.

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THE SURFACE CONFIGURATION OF THE ATLAS LANDS

HENRY MADISON KENDALL

THE usual description of the surface of northwest Africa includes the statement that this area is one of folded mountain ranges disposed along two southwest–northeast lines, with one transverse connecting chain flanked by complementary plateaus (Fig. 1). The Rif, the Tellean Atlas, the High Atlas, the Anti-Atlas, and the Saharan Atlas are classed as folded mountains differing mainly in height. The Middle Atlas has to its west the Moroccan Meseta and to its east the Plateau of the Shotts. There are fringing coastal plains along the Moroccan and Tunisian coasts. Beyond this, the character of the surface is left largely to the imagination. It cannot be questioned that the division suggested has many uses of convenience, that its basis in tradition is well founded, and that it may provide the imaginative with some notion of origin. That it describes satisfactorily the nature of the broader types of surface must be denied.

An attempt is here made to suggest the kinds of surface which are found in the Atlas Lands and to indicate the pattern in which they occur. The inquiry relates to surface, particularly as regards relief and slope, and the unit indicating the scale of inquiry is the Atlas Lands as a whole. Compilation was made on a base with the scale of 1 : 2,000,000. Source materials included the sheets of the International Millionth Map of the World; the maps of the French Army geographical service on the scale of 1 : 200,000 for most of the area and on larger scale for some parts; and works of French geographers, notably those of Bernard, Ficheur, Gautier, Gentil, and Solignac.[1] In the construction of the final map (Fig. 2) four main

[1] The following works are especially significant:

Bernard, A., *Afrique septentrionale et occidentale*. Volume 11, Part I, *of Géographie universelle*. Paris, 1937.

Bernard, A., et Ficheur, E., "Les Régions naturelles de l'Algérie," *Annales de Géographie*, 11 : 221–246, 339–365, 419–437. 1902.

types of surface were distinguished: plain, hilly land, tableland, and mountain.[2]

When the distribution of the four types was plotted certain agreements with and certain variations from the usual concept of the surface of the Atlas Lands appeared (Fig. 2). The High Atlas remains as a zone of mountain land stretching from southwest to northeast across the southern portion of Morocco. Extending to the north are the transverse mountainous Middle Atlas and, to the south, the

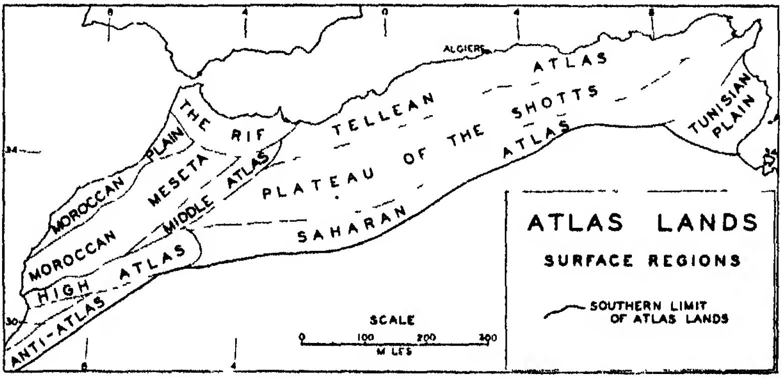

FIG. 1. Northwestern Africa· surface regions

subparallel mountainous Anti-Atlas. The Middle Atlas is narrowly joined to the north flank by a series of high ridges. A huge deeply dissected volcanic mass blocks the gap between the High Atlas and the Anti-Atlas. To the north and west of the Middle Atlas and not joined to it lies the crescent-shaped Rif, a mountain zone with fringing hilly and tabular piedmont. These are the four main mountainous areas of the region.

The Tellean Atlas and the Saharan Atlas are not mountainous

Bernard, A., et de Flotte de Roquevaire, R., *Atlas d'Algérie et de Tunisie.* Paris, 1924—.

Bernard, A., *L'Algérie.* Paris, 1929.

Gautier, E. F., *Structure de l'Algérie.* Paris, 1922.

Gentil, L., *Le Maroc physique.* Paris, 1912.

Solignac, M., *Carte géologique de la Tunisie à 1: 500,000.* Paris, 1931.

[2] For a summary of definitions see V. C. Finch and G. T. Trewartha, *Elements of Geography* (New York, 1936), pp. 319, 416, 428, 443. See also P. E. James, "The Surface Configuration of South America," *Pap. Mich. Acad. Sci., Arts, and Letters,* 22 (1936): 369–372. 1937.

in the greater part of their extent. To be sure, the dominance of folded structure in the Tellean area is unquestioned, but variations in amplitude of folding and in magnitude of dissection produce a complex pattern of plains, hilly lands, and mountains. The pattern in the Saharan Atlas is considerably less complex, though the concept of a continuous mountain chain is there equally misleading. Structurally, a zone of folding extends eastward in rough continuation of the individual ridges of the High Atlas, but only the higher

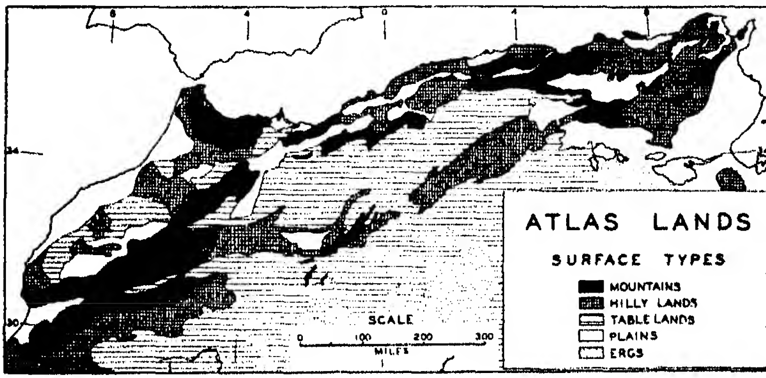

FIG. 2. Northwestern Africa: surface types

parts project through the horizontal sedimentaries, which lie both to the north and to the south. In the central section it is difficult to distinguish any evidence of relief great enough to suggest even a hilly land. In comparison with the High Atlas this is certainly not a mountain land, except for two relatively small areas.

The surface of the Plateau of the Shotts is broken in a few places by hilly zones and by basins of interior drainage. Except for the easternmost basin none of the interruptions are on a sufficiently large scale to destroy the concept of tableland.

There is great variation from place to place over the surface of the Moroccan Meseta. An escarpment of between 300 and 500 feet elevation marks part of the contact with the plain on the west, but it is not continuous along the whole contact. Abrupt change to mountains is noted along the southern and part of the eastern margins. The materials upon which the present surface is developed include recent alluvium, massive crystallines, horizontal-lying sedi-

mentaries, and sharply folded sedimentaries. The area is in part plain, in part hilly land, and in part tableland.

Along the west coast of Morocco and along the east coast of Tunis there are small areas of plains.

University of Michigan

LIPSZKY'S MAP AND THE FIRST GENERAL LAND SURVEY OF HUNGARY (1786–1806)

GEORGE KISS

MAPS are among the best monuments of a culture, of the civilization and history of an age. Their technique reflects the degree of cartographical skill; their accuracy shows the attainments of surveyors and astronomers; the amount of information recorded is characteristic of the state of geographical knowledge; the type of execution indicates the artistic skill and taste of the period. The great map of Hungary published by John Lipszky in 1806 offers an excellent example of the craftsmanship, skill, good taste, and scholarly accomplishments of early modern cartographers in Europe.[1]

In 1806, when Lipszky published his map, Hungary, the eastern half of the Habsburg monarchy, was in many respects a medieval country. Certainly its social system lagged far behind those of the more advanced countries of western Europe. Hungarian nobility held under its power millions of serfs who, although assured of a livelihood on their tenant farms or on the great estates, were deprived of all political rights.

At the dawn of the nineteenth century Hungary was a country of great herds of cattle and sheep, of charming, sleepy little towns, surrounded by orchards and vineyards, a country of stagecoaches rattling along some of the most impassable roads of the continent. It was a land of rivers sluggishly rolling through hundreds of miles of marshes, a land of great primeval forests, where thousands of pigs were fattened on acorns and where the "gentlemen of the highway" plied their none-too-prosperous trade. It was a country where trade was restricted to the cities and carried on with great difficulty along the few highways and on the rivers, and where the great estates

[1] The copy of Lipszky's map on which this study is based is part of the library of Professor Robert B. Hall, of the University of Michigan, to whom the author is indebted for permission to use it.

with their châteaux built in imitation of Versailles rubbed elbows with the thatch-roofed hut of the serf; it was a source of raw materials, wheat, meat, metals for the growing trade and industry of Austria.

This was the land we find so truthfully represented on Lipszky's great map, a land on the threshold of the modern era, perhaps the most backward part of Central Europe at the time. Lipszky certainly did pioneer work in many respects, yet he was not without predecessors. Let us consider briefly the developments that antedated the publication of his map.

It was in the first or second decade of the sixteenth century that Lazarus, secretary to Archbishop Bakócz, Primate of Hungary, published a map of Hungary in Vienna.[3] This was the first map of the country prepared by a Hungarian, and it served, with later corrections, as a base for the Hungarian sheets of the great atlases of Mercator, Münster, Ortelius, and others. During the sixteenth and seventeenth centuries, when the Turk occupied the greater part of Hungary, most maps of this country were published abroad, based on the rather scanty and often inaccurate information received by the map makers. Wit's map of Hungary, of 1688 (Fig. 1), gives a good idea of the distortion we find on maps of this period.

After 1700 detailed cartographic work was started by the Austrian government; it was carried out mostly by French, German, and Italian military surveyors. At the same time maps were published by civilian cartographers. The map of John Christopher Müller, of 1709, on a scale of 1 : 550,000, and the map of Ignaz Müller, of 1769, on a scale of 1 : 360,000, were the most notable ones among these.[4]

The eighteenth century witnessed the rise of new political and economic systems throughout Europe. Mercantilism was adopted by Austria-Hungary, with a resulting expansion of both manufacture and foreign trade, based on the resources of the realm. The need for accurate and detailed information about the state of the empire transformed map making from the inaccurate sketching of the preceding era into a highly important undertaking, initiated and carried out by the state. The ruler of Austria-Hungary, Maria Theresa,

[3] Prinz, Gyula, *Magyar Földrajz — Magyarország tájrajza* ("Hungarian Geography — Regional Geography of Hungary"), I: 74 ff. Budapest, 1936.

[4] Irmédi-Molnár, László, "Magyar térképekről" ("About Hungarian Maps"), *Földrajzi Zsebkönyv* ("Geographical Yearbook"), 1939, p. 178. Budapest, 1939.

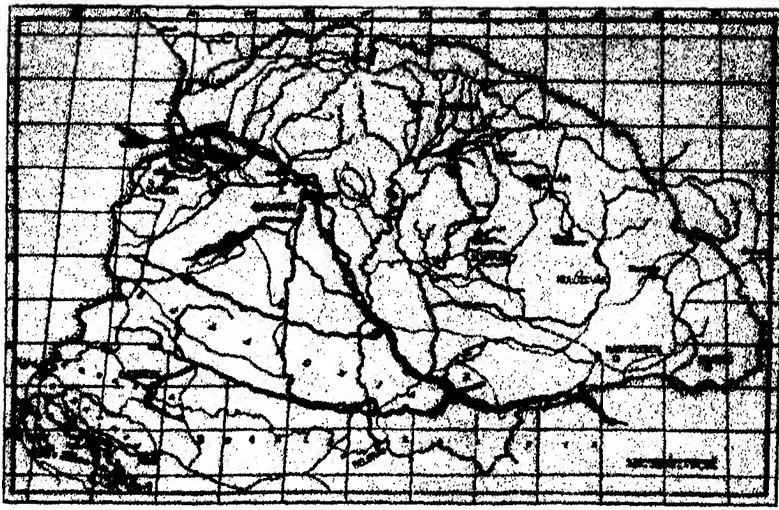

FIG. 1. Wit's map of Hungary, published in 1688. The dotted lines represent boundaries and the double lines rivers as they appear on a modern map; the heavy lines, the distortion given by the old map

ordered the surveying of all her domains in 1763, and this survey was executed on a scale of 1 : 28,800.[4] Completed by 1785, on some three thousand sheets, this first or "Josephine" survey of Austria-Hungary (named after Joseph II, son and successor of Maria Theresa) was executed by officers of the Austrian army. The sheets were withheld from publication, and individuals did not have access to them. It was only as a major in a cavalry regiment, and former army surveyor, that Lipszky obtained permission to make use of these maps in the compilation of his work.

The "Josephine" survey was followed by another military survey, executed by the Austrian Military Topographical Institute, on a geodetical basis, between 1807 and 1868.[5] This, in turn, was followed by the first modern survey of Austria-Hungary, on a scale of 1 : 75,000.

Because of his privileged position and the permission he obtained to use the detailed maps of the military survey Lipszky was able to produce a map far more accurate than those of any of his predecessors. And, in addition to the information available on the 1,451 sheets of the "Josephine" survey on Hungary, he had recourse to

[4] Prinz, *op. cit.*, p. 78. [5] *Ibid.*, p. 79.

Fig. 2. A surveyor and his aides (from Lipszky's map). The peasant on the left is dressed in Rumanian costume of the early nineteenth century; the one on the right, in Hungarian costume of the same date

some of the material collected throughout Hungary in 1784–85, by the General Land Survey, ordered by Joseph II.

This General Land Survey has a unique position in Hungarian history. It was the first modern census of the country, yet most of the results obtained were destroyed by certain groups whose interests were endangered by the intentions of the Survey. Hungary had preserved the institution of serfdom until 1848, but the nobility was exempted from taxation. Both Charles III and Maria Theresa had attempted to induce the nobility to contribute its share to the finances of the state. Although each of these attempts was unsuccessful, Joseph II, a ruler deeply impressed by the ideas current at the time in Europe and anxious to achieve an ideal state of religious and personal liberty within his own realm, ordered a general land survey to be carried out in 1784–85. This survey, coupled with a census of the population, was to provide data on land use and on the income of nobility, bourgeoisie, and serfs alike. Although the survey was completed, in many places with the help of the army,

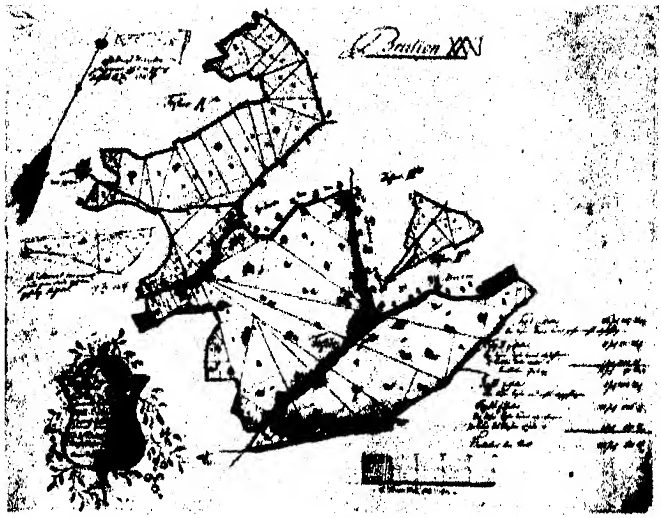

FIG. 3. Preliminary field sketch (*brouillon*) of a part of Zala County, western Hungary, executed by Joseph Badstieber, topographic engineer, for the General Survey of 1784–85

most of the material collected — sketches, field notes, income returns — had been destroyed in 1787–88 by the wrath of the gentry, who were reluctant to give up their old privileges.[6]

The instruments used in the two surveys, the "Josephine" survey and the General Land Survey, which served as bases for Lipszky's work, are depicted on the map itself (Fig. 2). They are the chain, the sextant, and the plane table. To determine rectangular lines the surveyors also used the "Egyptian triangle," an application of a Pythagorean principle. The field sketches were quite accurate, and many were executed with great skill (Fig. 3).

Let us now turn our attention to Lipszky's map (Pl. I, Fig. 1), entitled: "General Map of the Kingdom of Hungary, of its annexed

[6] See Irmédi-Molnár, László, "Az 1786. évi Kataszteri felmérés Zalavármegyében" ("The Cadastral Survey of 1786 in Zala County"), *Földrajzi Közlemények* ("Geographical Review"), 67 (1939): 330–340. Budapest, 1939.

Fördős, László, *A II. József-féle kataszteri földmérés Magyarországon* ("The Cadastral Survey of Hungary under Joseph II"). Szeged, 1931.

Föglein, Antal, "A 'Conscriptio Josephina' sorsa" ("The Fate of the 'Conscriptio Josephina'"), *Levéltári Közlemények*, (Communications from the National Archives), 9: 112–119. Budapest, 1931.

parts, Croatia, of Slavonia and the Military Border areas, also of the Grand Duchy of Transylvania; based on geometrical measurements of distances and dimensions, and on the most recent astronomical observations. Containing also adjacent parts of the provinces of Bukovina, Galicia, Silesia, &c. . . . Dedicated to His Royal Highness Archduke Joseph, Prince Palatine of Hungary, by John Lipszky, Major in the 'Baron Kinmayer' Cavalry Regiment." The map, which was published in Pest in 1806, measures 80 by 49.5 inches. It was engraved by Francis Karacs, the most accomplished engraver of his time, author of the first modern Hungarian atlas.[7]

The scale of the map is 1 : 460,000. It may still be used in the field; its accuracy of detail makes it an invaluable instrument for every research project concerned with Hungarian conditions in the late eighteenth and early nineteenth centuries. Its wealth of material should be attributed to the efforts of the compiler and cartographer and to the excellent technique of the engraver. It represents not only small villages and hamlets, but also isolated settlements of but one or two houses, industrial establishments, roads, canals, ferries, bridges. It also shows the exact extent of marshy areas, forests, and swamps as they existed about 1800 (Pl. I, Fig. 2).

Among the many interesting characteristics of Lipszky's map its method of reproducing place names is of great interest. It usually gives the name of a village or town in the language of the majority of its inhabitants and in Latin, followed by the name of the village in other tongues spoken in that vicinity. Thus we may attempt a reconstruction of the distribution of national minorities in Hungary about 1800.

Of the many maps of Hungary published in the late eighteenth and early nineteenth centuries none can be compared with this great work. Its impartial way of representing disputed place names and conflicting administrative boundaries, its highly perfected cartographical technique, and the artistic skill of draftsman and engraver make it a truly important document of early modern Hungarian geography and a splendid monument to its author and publisher, John Lipszky.

University of Michigan

[7] Irmédi-Molnár, *op. cit.*, p. 180.

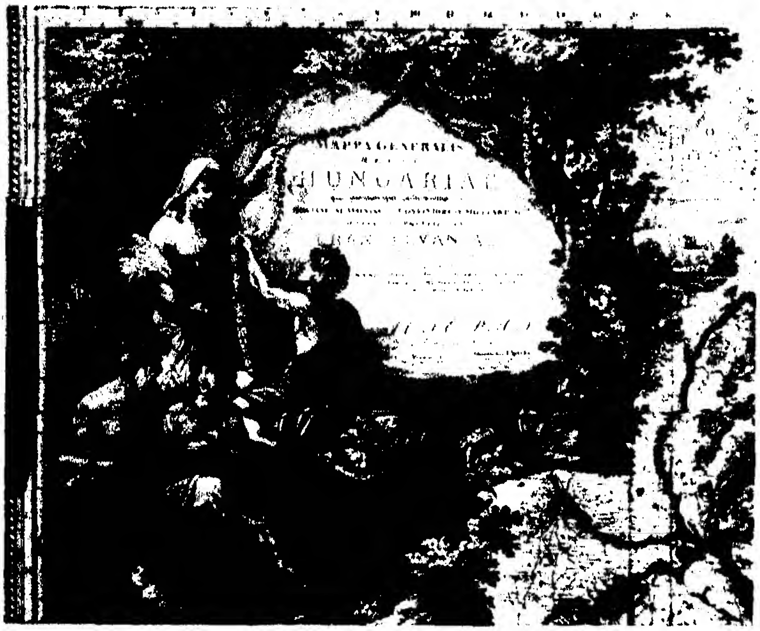

FIG. 1. Cartouche and title on Lipszky's map

FIG. 2. Detail from Lipszky's map, showing the vicinity of Pozsony, in northwestern Hungary

CHANGES IN DISTRIBUTION OF FARM BUILDINGS IN RELATION TO LAND TYPES, CHARLEVOIX COUNTY, MICHIGAN *

IVAN F. SCHNEIDER

CHARLEVOIX COUNTY is in the cutover section of northern Michigan on the northwest side of the Lower Peninsula adjacent to Lake Michigan. In this county land was first cleared for agricultural use in the early part of the eighteen fifties. Agricultural development continued as the virgin forests were removed until at the present time almost 50 per cent of its land area is included in farms.

Since the success or the failure of farming ventures depends to a large extent upon the character of the land, a study of the changes in the number and the distribution of farm buildings on the natural land divisions between 1922 and 1940 was made in an effort to determine: (1) whether the quality of the land is related to the changes in farm buildings; (2) whether agricultural expansion has reached its peak; and (3) whether any predictions can be made of the future trend of agriculture in Charlevoix County.

In this investigation it was assumed that an occupied farm dwelling was indicative of an active farm unit and that changes in the number and condition of rural buildings reflected the trend of land use.

Information on which the study was based was obtained from the data of two surveys: (1) the survey of the Land Economic Survey division of the Michigan Department of Conservation, made in 1922, which inventoried the natural resources of the county, and also located all the rural dwellings and indicated whether they were occupied or vacant; and (2) the land-type survey sponsored in 1940

* **Authorized as Journal Article No. 587 (N. S.) from the Michigan Agricultural Experiment Station.**

by the Michigan Agricultural Experiment Station, in coöperation with other agencies, which not only gave the location of rural buildings and their state of occupancy, but also listed their condition. The following rating system for farms, which has been standardized on a state-wide basis, was used:

Excellent farm (A). — Very large house, barns, and other buildings; all in excellent condition. The largest and most prosperous farms in the state.

Good farm (B). — Well-kept buildings with modern improvements. Evidence of a large volume of farm business.

Average farm (C). — Buildings of adequate size and not in need of major repairs. The average Michigan farm.

Poor farm (D). — Buildings either small or in a poor state of repair. Little money or labor expended for maintenance in recent years.

Very poor farm (E). — Buildings small and in a condition that indicates they will probably become uninhabitable within a few years unless better maintained than in the past.

Vacant farm (F). — Buildings inhabitable but not occupied.

Buildings gone or in ruins (G). — Farmstead uninhabitable.

Rural residence (R). — Income of occupant derived wholly or largely from sources other than agriculture.

For the present study the land types mapped in Charlevoix County in 1940 were arranged in eleven broad land divisions based on topography, drainage, and the texture of the soil. A relative agricultural rating was given each of the natural land divisions. Brief descriptions of each follow:

Sand, plains and dunes. — Sand dunes; sand plains, dry to poorly drained; gravel ridges; and low lake benches. Fourth-class agricultural land. Soil types — Bridgman sand, Rubicon sand, Eastport sand, Alpena sandy loam, Saugatuck sand, and Newton sand.

Sand, valleys. — Level sandy valley floors surrounded by steep hills. Soils droughty and low in natural fertility. Third- and fourth-class agricultural land. Soil types — Kalkaska and Rubicon sand.

Sand, lake benches. — High level sandy lake benches. Soils droughty and low in natural fertility. Third- and fourth-class agricultural land. Soil types — Kalkaska and Rubicon sand.

Sand, hills. — Hilly sandy land, with some extremely rough areas. Substratum predominantly sand. Low natural fertility. Third- and fourth-class agricultural land. Soil type — Emmet sand.

Sandy loam, valleys. — Narrow, level sandy loam valley floors surrounded by steep hills. Surface soils varying from a sandy loam to a loam and underlain at one to three feet by gravel, cobbles, or clay. Second-class agricultural land. Soil type — Antrim sandy loam.

Sandy loam, undulating. — Level to undulating sandy loam uplands, generally underlain by sandy clay at two to three feet. First- and second-class agricultural land. Soil type — Emmet sandy loam.

Sandy loam, hilly. — Hilly sandy loam. Surface varying from a loamy sand to a sandy loam, underlain by sandy clay at two to three feet. Second- and third-class agricultural land. Soil type — Emmet sandy loam.

Loam, lake benches. — Loam. Higher lake benches locally wet and underlain by clay. Level to undulating topography. Second-class agricultural land, except in extremely stony areas or in places where drainage is required. Soil types — Kawkawlin loam, Bowers loam, Munuscong loam, and Bergland loam.

Loam, undulating. — Level to undulating loam uplands, usually underlain by clayey substratum at two to three feet. First-class agricultural land. Soil type — Onaway loam.

Loam, hilly. — Drumlins. Rolling to extremely hilly; loam over clayey substratum. Productive soil, but its value for agricultural use is limited by the large number of steep slopes. Soil type — Onaway loam.

Swamp, level. — Swamps, marshes, and bogs. Fourth-class agricultural land. Soil types — *Carbondale muck, Rifle peat, and Greenwood peat.*

FARM-BUILDING CHANGES BETWEEN 1922 AND 1940

The total number of farm buildings tabulated from the 1922 map of the Land Economic Survey was 1667. At that time 1320 were occupied and 347 were vacant. Eighteen years later the number had increased to 1712, of which 1155 were occupied and 557 were either vacant or simply indicated locations of former farm enterprises (Table I).

TABLE I

Occupied and Vacant Farm Buildings in 1922 and 1940

Year	Occupied	Vacant	Total
1922	1320	347	1667
1940	1155	557	1712

A breakdown of the data reveals that three changes in the occupancy of farm buildings had taken place: (1) those occupied in 1922 and either occupied or vacant in 1940; (2) those vacant in 1922 and either occupied or vacant in 1940; and (3) those erected since 1922 and either occupied or vacant in 1940.

By means of Tables II–IV the changes in number, distribution, and condition of farm buildings can be studied in relation to the

TABLE II

THE 1940 CLASSIFICATION OF THE RURAL BUILDINGS THAT WERE OCCUPIED IN 1922

(The abbreviations used in Tables II–IV are explained on page 456.)

Natural land divisions	A	B	C	D	E	R	F	G
Sand, plains and dunes	..	..	3	...	4	5	1	6
Sand, valleys	..	2	12	36	47	5	23	37
Sand, lake benches	..	1	8	16	3	6	4	7
Sand, hills	..	..	5	34	52	7	22	47
Sandy loam, valleys	..	3	27	22	8	7	11	3
Sandy loam, undulating	..	14	58	56	10	2	13	10
Sandy loam, hilly	..	1	30	107	32	8	18	13
Loam, lake benches	1	..	15	25	8	6	4	8
Loam, undulating	..	20	129	57	2	10	9	6
Loam, hilly	..	6	70	57	18	3	13	7
	Occupied 1058						Vacant 262	
Total	1320							

TABLE III

THE 1940 CLASSIFICATION OF THE RURAL BUILDINGS THAT WERE VACANT IN 1922

Natural land divisions	C	D	E	R	F	G
Sand, plains and dunes	..	..	..	..	..	3
Sand, valleys	..	4	7	1	9	33
Sand, lake benches	1	..	..	2	..	5
Sand, hills	1	2	8	1	7	57
Sandy loam, valleys	1	3	..	2	3	7
Sandy loam, undulating	3	1	1	..	6	10
Sandy loam, hilly	3	8	11	1	8	42
Loam, lake benches	2	1	3	2	..	10
Loam, undulating	10	7	..	2	2	12
Loam, hilly	5	4	5	3	10	18
	Occupied 105				Vacant 242	
Total	347					

TABLE IV

THE 1940 CLASSIFICATION OF THE RURAL BUILDINGS THAT HAVE BEEN CONSTRUCTED SINCE 1922

Natural land divisions	C	D	E	F	G
Sand, plains and dunes	..	..	..	..	..
Sand, valleys	..	3	14	7	4
Sand, lake benches	..	..	2	2	..
Sand, hills	1	3	10	5	9
Sandy loam, valleys	..	1	4	..	..
Sandy loam, undulating	2	..	4	1	4
Sandy loam, hilly	1	3	9	3	12
Loam, lake benches	1	..	1	..	1
Loam, undulating	3	1	..	..	..
Loam, hilly	2	..	..	..	5
	Occupied 65			Vacant 53	
Total	118				

eleven natural land divisions. Reference to them will show, for instance, that 162 occupied buildings were located on the sandy valley land in 1922.

What happened to them in the eighteen-year period? Only 102 were still occupied in 1940 (Table II). These were classified as follows: 2 good farms; 12 average farms; 36 poor farms; 47 very poor farms; and 5 rural residences. Sixty unoccupied farmsteads existed, of which 23 were inhabitable, and 37 were uninhabitable.

Fifty-four vacant houses were tabulated on the sandy valley land division in 1922 (Table III). Twelve of these farms were occupied in 1940, of which 4 were classified as poor farms, 7 as very poor farms, and 1 as the home of a rural resident. Forty-two were still unoccupied in 1940, with 9 in the inhabitable class and 33 in the uninhabitable class.

Twenty-eight new farm units have been erected on the sandy valley land division since the 1922 survey (Table IV). Of these farms 17 were occupied in 1940, with 3 in the poor class and 14 in the very poor class. Of the 11 farm buildings that had been abandoned 7 were classified as inhabitable and 4 as uninhabitable.

In summarizing these changes on a county-wide basis it was found that in 1922 there was a total of 1320 occupied houses in

Charlevoix County, whereas in 1940 only 1058 were still occupied (Table II). On the other hand, 105 of the 347 farm buildings vacant in 1922 were occupied in 1940, whereas 242 had remained vacant or had become uninhabitable (Table III). One hundred and eighteen farm buildings had been erected since 1922, and the 1940 survey indicated that 53 of these dwellings had already been vacated. People still resided in 65 of them (Table IV).

Further examination of Tables II–IV reveals a number of interesting conditions. Almost 50 per cent of the 118 farmsteads established between 1922 and 1940 have already failed (Table IV). It seems significant that 80 per cent were situated on but three of the natural land divisions, namely, the level to undulating sandy valleys, the sandy hills, and the sandy loam hills. Seventy per cent of the farm buildings vacant in both 1922 and 1940 were also located on the same natural land divisions (Table III). Sixty per cent of the houses occupied in 1922, but vacated before 1940, were on the same land divisions (Table II).

OCCUPIED FARMS IN 1922 AND 1940

The number of occupied farm buildings on each of the natural land divisions in 1922 and 1940 was compared, and the percentage of decrease of the occupied farm buildings was calculated for each division (Table V). No buildings were tabulated on the swamp land division in either survey. The table reveals that, although the number of farm units decreased over the eighteen-year period on all the natural land divisions, the percentage of change on the heavier soils was relatively small. The 15 per cent decrease on the loam lake bench division, which is rather good farm land, can be accounted for because of the inclusions of poorly drained clay land and the extremely stony and bouldery soil in the natural land division. The 9 per cent decrease in the undulating sandy loam that is also good land is partially due to the abandonment of farm buildings in the Chandler Hill area in the eastern part of the county. Factors that caused the vacancy of these buildings were: (1) the existence of an island of productive land surrounded by sparsely settled sandy land from which the removal of the timber had eliminated all opportunity for securing supplemental income in the winter by working in the woods; (2) the difficulty of obtaining an adequate water supply; and (3) the consolidation of farm units. On the four sandy

TABLE V

LOCATIONS OF OCCUPIED FARM BUILDINGS IN 1922 AND 1940 ACCORDING TO NATURAL LAND DIVISIONS

Natural land divisions	1922	1940	Change	Percentage of change
Sand, plains and dunes	19	7	− 12	63
Sand, valleys	162	125	− 37	23
Sand, lake benches	45	31	− 14	31
Sand, hills	167	116	− 51	31
Sandy loam, valleys	81	69	− 12	15
Sandy loam, undulating	163	149	− 14	9
Sandy loam, hilly	209	205	− 4	2
Loam, lake benches	67	57	− 10	15
Loam, undulating	233	229	− 4	2
Loam, hilly	174	167	− 7	4
Totals	*1320*	*1155*	− *165*	13

land divisions the decrease in occupied units ranged from 23 to 63 per cent.

1940 FARM-BUILDING CLASSIFICATION

The 1940 farm-building classification has been summarized by the natural land divisions (Table VI). The second column of this table indicates the number of occupied farm buildings, vacant farm buildings, or farm-building ruins on each land division. The total number of occupied and vacant farms was computed from Tables II–IV and is recorded in the third and fourth columns. By dividing the number of occupied farm buildings by the total number of farm buildings an agricultural success index has been calculated for each natural land division. These data are recorded in the fifth column of Table VI. A study of the indexes discloses that the level to undulating loams and level to undulating sandy loams are most suitable for agricultural use, since 89 and 77 per cent respectively of the farm units located upon these types were relatively successful. Further study reveals that the level to undulating sandy valleys, the rolling to hilly sandy land, and the sand plains and dunes constitute the poorest types for farming, since their agricultural success indexes were only 52, 44, and 41 per cent respectively.

A further analysis of Table II shows that in the sandy valley

TABLE VI

1940 Farm-Building Classification by Natural Land Divisions

Natural land divisions	Number	Occupied	Vacant	Agricultural success index
Sand, plains and dunes	17	7	10	41
Sand, valleys	238	125	113	52
Sand, lake benches	49	31	18	62
Sand, hills	263	116	147	44
Sandy loam, valleys	93	69	24	74
Sandy loam, undulating	193	149	44	77
Sandy loam, hilly	301	205	96	68
Loam, lake benches	80	57	23	71
Loam, undulating	258	229	29	89
Loam, hilly	220	167	53	76
Totals	1712	1155	557	67

land division 36 occupied farms were classified as poor and 47 as very poor, whereas in the sandy hill division 34 were classified as poor and 52 as very poor. The undulating loam land division, however, has 20 good farms, 129 average farms, 57 poor farms, and only 2 very poor farms. If the trend of the last eighteen years continues, between 30 and 40 per cent of the farm units on the sandy land divisions will become abandoned in the next twenty years. On the heavier-textured soils, however, only a slight decrease in the number of occupied farm buildings is in prospect.

RECREATIONAL DEVELOPMENT

The reversals indicated by the changes in occupancy that have taken place are offset in some degree for the county as a whole by the expansion of recreational dwelling units. The 1922 survey showed only 79 cottages, including summer homes and hunting cabins, in Charlevoix County. The 1940 survey, however, identified a total of 633 such developments, or eight times the number in 1922. The increase is due to the recreational attraction of Lake Charlevoix and its South Arm, Walloon Lake, and Lake Michigan, coupled with the improvement of Michigan's highway system and also automotive transportation, both of which have assisted in stimulating this rapid recreational expansion.

CONCLUSIONS

1. If one uses the number and condition of farm buildings as a criterion, it becomes apparent that the agricultural use of the land in the last eighteen years has remained relatively stable on the better soils and has decreased on the poorer soils.

2. The agricultural success index as determined by the number of occupied and vacant farm buildings on the various land divisions correlates closely with the soil productivity indexes of the natural land divisions.

3. Some agricultural expansion is still in progress, but it is evident that the recent pioneers are not settling on the more productive soils.

4. The relatively large number of farm failures on the sandy valley and the sandy hill land divisions and the tendency of recent pioneers to settle upon the less productive soils indicate the need of zoning controls to reduce the number of unsuccessful farm enterprises.

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AN AREA ANALYSIS OF HUMPHREYS COUNTY, TENNESSEE

H. THOMPSON STRAW

THE area analysis of Humphreys County, Tennessee, is one of a limited number of experimental studies designed to test a simplified technique as it might be applied to the problems of unemployment. The National Resources Planning Board, in coöperation with the Bureau of the Budget, is charged with the programing and the evaluation of most construction and public works proposals. In order to provide a background of specific and regional information against which individual projects and programs could be reviewed a technique, commonly referred to as the "Colby technique," was devised. The present study is one of several completed under the direction of the Southern Studies Project.[1] These studies, together with the papers prepared by members of other departments of geography and by the National Resources Planning Board itself, will form the bases of judging the efficacy of the method of work. This particular paper is an attempt to condense a much longer original report, and yet give some idea of the results of the technique. The method outlined by the Board has been followed not only in the collection of material but also, so far as the limitation of the paper permits, in its presentation.

Humphreys County is located west of the central part of Tennessee and is one of about ten similar political units that comprise the upland hilly region which lies immediately west of the Nashville Basin and which is usually referred to locally as the Western Highland Rim (see Fig. 3). The county is predominantly rural and is in one of the less fertile sections of the Corn and Winter Wheat Belt.[2] Too far north for the successful production of cotton and

[1] Sponsored by the Committee on Geographic Research, Division of Geology and Geography, National Research Council, with Dr. Preston E. James as chairman.

[2] Baker, O. E., "Agricultural Regions of North America. Pt. III. The Middle Country Where South and North Meet," *Econ. Geog.*, 3 (1927): 309–353.

too far from the established tobacco markets to make tobacco raising profitable, it is therefore without a dominant cash crop and has the greatest amount of its cultivated land in corn. The general picture that has already been painted for the entire Rim land [3] is one of self-sufficient farms of low income, widespread illiteracy, inadequate schools and roads, and substandard houses lacking even such conveniences as telephones and electric lights, and that general picture is fairly true of this county in particular. The relief loads in the past have been high, and so has the amount of state aid for services such as the schools.

Any attempt to make recommendations for the future development of the county must take into consideration the fact that the building of the Gilbertsville Dam by the Tennessee Valley Authority and the establishment of the Kentucky Reservoir will result in the inundation of the entire western strip of the county lying adjacent to the Tennessee River. The completion of the reservoir means the removal of some 21,000 acres from cultivation, and, significantly, the lands so removed have been accounted in the light of past agricultural practices to be among the best croplands of the area. The income of the county's inhabitants, which has been below the level of those of both the state and the nation, is thus threatened with further curtailment.

CHARACTERISTICS OF EMPLOYMENT

Population and the Employment Problem

As has been stated before, Humphreys County is predominantly rural and agricultural. There are, however, two small towns, Waverly, with a population of 1,318, and McEwen, with a population of 617, which together comprise 15.5 per cent of the population of the county. Since manufacturing, except for the processing of local raw materials such as timber and grain, scarcely exists, the towns are transportation, service, and county-seat centers.

Humphreys County is similar to many other Southern upland areas in its small proportion of Negroes and in the general pattern of its population growth. In 1930 the Negro population constituted but 6 per cent of the total population of the county, a steady decline from the 14.7 per cent of 1880 (Fig. 1). During the intervening

[3] Lucas, Broder F., and Callahan, E. P., *Major Rural Land Use Problems in Tennessee*, p. 11. Nashville, Tenn.: Tenn. State Planning Comm., 1936.

fifty years the Negro population had decreased not only proportionately but numerically as well, with many of the Negroes migrating from the upland area to the near-by lowlands, especially to the cotton-growing section about Memphis to the west.[4] In population growth the county is very similar to those which share its

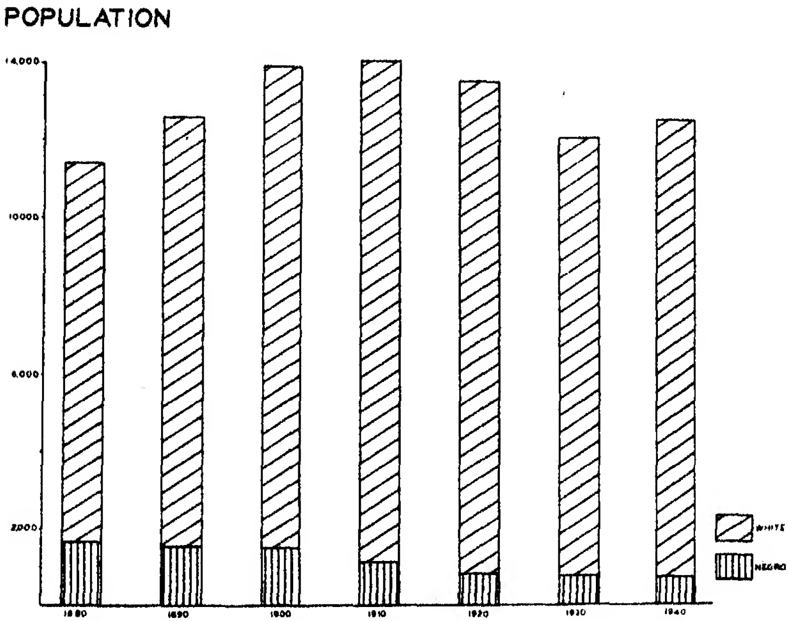

Fig. 1. Population growth of Humphreys County, Tennessee, 1880–1940

upland position. A slow growth from the date of settlement in 1800 reached a climax in 1910 (Fig. 1). The next two decades saw an actual decline brought about by the migration of workers to other parts of the state or the nation that offered greater economic opportunities. Better transportation and improved education were important factors in making this migration possible. In the past decade a reversal of this trend has taken place, for the population has again increased. Fewer economic opportunities, especially in the urban centers that had probably attracted many of the earlier migrants,

[4] *Preliminary Population Report*, Sec. IIA, pp. 8–11. Nashville, Tenn.: Tenn. State Planning Comm., 1935.

resulted in keeping at home many of the younger people who would normally have migrated, and have even caused the return of some who had formerly migrated from the county.

In its early history lumbering was of great importance, but the distribution of occupations within the county today, as shown in Figure 2, gives preëminence to agriculture. Of the 2,278 persons employed 80.4 per cent are engaged in farming, of whom the large majority, 87.7 per cent, are farm operators. Of the business and industrial group, it is significant that the number of proprietors

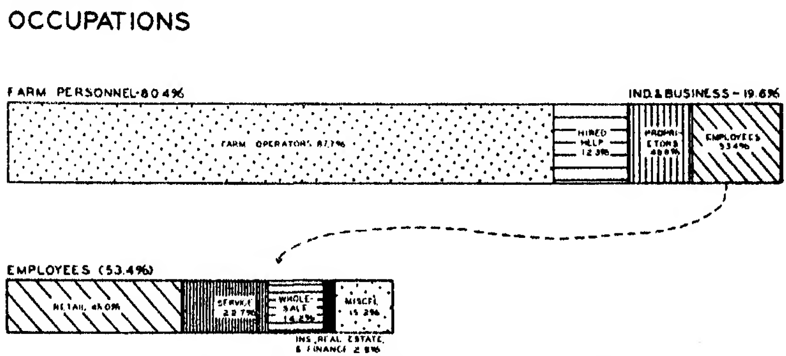

FIG. 2. Occupations in Humphreys County, Tennessee, 1935

(46.6 per cent) nearly equals that of the employees (53.4 per cent), a definite indication that most of the business and industrial establishments of the county are small. Retail and service types predominate among the employees.

Description of Unemployment

The unemployment census of 1937 [5] presents a clear picture of the types of additional work needed in the area. Among the males the largest groups of unemployed were laborers, skilled and semiskilled workers, and farmers. The majority registering were farm laborers, and of these the number of persons who were partly unemployed was nearly two and one-half times as large as the number of those who were totally unemployed. Thus the need of supplementary employment for those who work on the farm is very evident.

[5] Bureau of the Census, *Census of Partial Employment, Unemployment and Occupations: 1937*, III: 185, 381, 395. Washington, D.C., 1938.

The largest group of unemployed females consisted of young workers, although servant classes, semiskilled workers, and clerks added to their number. In general, on the basis of the number of registrants, unemployment among the men appears to be more extensive than among the women. Any future plans for emergency work, however, should include a larger percentage of work suitable for the smaller group than that offered at present in order to effect an equitable distribution between the two sexes.

It is interesting to note that the largest group of those registering as in need of employment was between the ages of 15 and 25, many of whom had become of employment age since the beginning of the depression. This age distribution further attests the seriousness of the cessation of migration in augmenting the problem of unemployment.

FACTORS AFFECTING EMPLOYMENT AND INCOME STABILITY

Basic Natural Resources

The major basic natural resources of the county consist of the climate, surface, and soils as related to agriculture and the forests. The climate is a transition between the humid subtropical and the humid continental (poleward Cfa of the Köppen classification). The rainfall is heavy, about 50 inches a year,[6] and the growing seasons average fewer than 200 days a year. Since this period is shorter than the recognized minimum required by cotton in the United States, the acreage devoted to this crop has been very small in recent decades.

Nor does tobacco, which frequently replaces cotton as the cash crop in the upper South, occupy more than a small acreage within the county. Its limitations are not the natural ones of climate or soil but distance from the markets, such as Clarksville, Tennessee, and Hopkinsville, Kentucky, and the policy of the administrators of the Agricultural Adjustment Act of limiting tobacco acreage.

Since Humphreys County lies within the Interior Low Plateau Province[7] it takes its major characteristics of surface from the

[6] United States Weather Bureau, "Western Tennessee," Sec. 76 of *Climatic Summary of the United States*, U. S. Government Print. Office, Washington, D.C., 1933, pp. 10, 17, 18.

[7] Fenneman, Nevin M., "Physiographic Divisions of the United States," *Ann. Assn. Am. Geog.*, 18 (1928): 307–309.

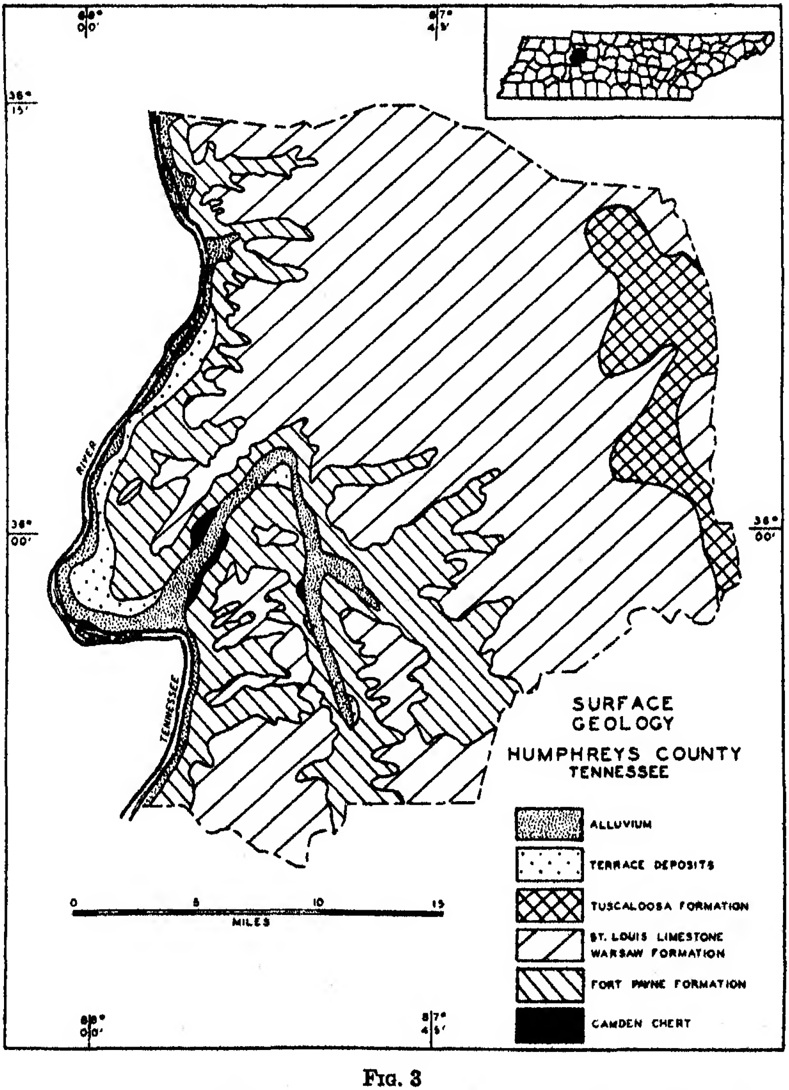

Fig. 3

(After Geologic Map of Tennessee, revised by W. F. Pond, Division of Geology, Nashville, Tennessee, 1933)

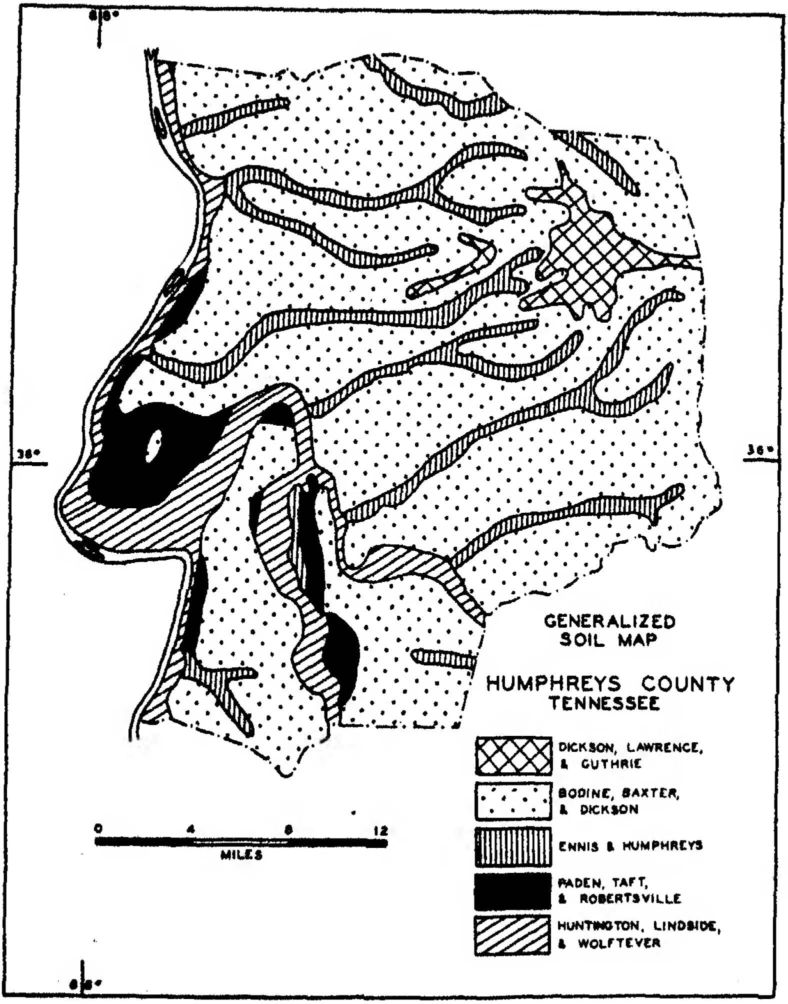

FIG. 4

(After G. M. Wells and others, "Soil Survey of Humphreys County, Tennessee," manuscript prepared by the Division of Soils Survey, in coöperation with the Tennessee Experiment Station and the Tennessee Valley Authority. Reproduced with permission of W. K. Kellogg, principal soil scientist)

larger area. Most of the rocks that underlie it are limestones and, like the remainder of the province, it has suffered a series of uplifts that have governed the rates of river erosion and deposition. Today four distinct types of surface can be recognized, and inasmuch as each is associated with one or two individual rock strata the geologic map is a fairly good basis for arriving at an understanding of the surface features. Each of these surface types has a characteristic soil association, since the soils are generally immature and derive most of their qualities from the weathered rock of the river deposit on which they develop.

At the highest elevation within the county is the first type of surface, the McEwen Upland, developed on the Tuscaloosa formation (Fig. 3). It occupies the broad, flat, and but slightly eroded portions of the plateau. Associated with it are Dickson, Laurence, and Guthrie soils, all of the second and the third class [8] (Fig. 4). Although the soil is generally suitable for agriculture, the inferior drainage in some areas and the tendency to erode in others discourage the tilling of crops and foster the development of dairying.

The second type of surface, which covers the major part of the county and is a mixture of narrow valleys and steep hills, is associated with the St. Louis limestone and the Fort Payne formation (Fig. 3). In the valleys the Ennis and the Humphreys soils are found (Fig. 4). These are of the first, second, and third class and are cleared and planted to crops such as corn, peanuts, and hay. The steep hills are covered with Bodine, Baxter, and Dickson, fourth- and fifth-class soils useful for some pasture but mainly for forest. Almost none of the area is suitable for tilled agriculture. Nevertheless there is a scattering of small cleared areas on which poor subsistence agriculture is practiced. In almost every one it is necessary to supplement the farm income, sometimes by work off the farm, but all too frequently by public relief aid.

The third surface division comprises the terrace deposits created by the rivers in earlier cycles (Fig. 3). The soils here are Paden, Taft, and Robertsville, generally of the second and third class (Fig. 4).

[8] The soils of the county have been generalized into five classes on the basis of productivity, workability, and the problem of conservation. The first three are those suitable for cropland, the fourth is suited to pasture, and the fifth to forest land. The results of the survey, still in manuscript form, were made available to the author at the office of J. W. Moon, senior soil scientist at Knoxville, Tennessee.

Since their use for cropland is restricted by a clay hardpan, by high acidity, and relatively low fertility, their importance is mainly for homestead sites, and the adjacent lower, seasonally flooded, but far richer, alluvium constitutes the cropland. Save for the clearings of the homesteads, much of the land of the terraces is in forest.

The last surface division, lying along the major streams, the Tennessee, Duck, and Buffalo rivers, is the recent river alluvium (Fig. 3). On its flat surface are the Huntington, Lindside, and Wolftever soils of the first- and second-class type (Fig. 4). Corn, peanuts, and lespedeza seed are the common summer crops, and many of the higher parts, less subject to flood, carry a winter crop such as wheat.

Essentials of Regional Economy

The population pattern of the county is distinctly a riverine one; most of the people live along the smaller creek bottoms or, if near one of the larger streams, on an adjacent river terrace where their homes are free from the danger of seasonal flooding (Fig. 5). A few have settled on the McEwen Upland in the northeastern part of the county, and a scattering is to be found on the ridges even where the slope is too steep for grazing. In 1930 the majority of farms on which these people lived were classified as self-sufficing (34.0 per cent) or general (23.6 per cent), figures which are approximately accurate today. Of the 2,691 houses, 41.9 per cent were judged substandard.[9] Only 109 of the farms have telephones, and only 80 are lighted with electricity. Corn, peanuts, lespedeza seed, and wheat are the basis of the lowland economy. The first two, corn and peanuts, are used to fatten hogs; the lespedeza seed and the wheat, in general, are sold as cash crops. The upland is devoted to subsistence farming and livestock, mainly dairy herds, since the cheese factory at McEwen furnishes a market for milk.

Seventy per cent of the county is still forested, largely by upland hardwoods. In 1937 there were twenty-four mills in the area, nine of them operating full time, each employing five men on the average and producing mainly crossties.[10] In addition, wood was shipped out of the county for chemical use and for chestnut extract. Ten-

[9] Tennessee Emergency Relief Administration Rural Housing Survey. See *Preliminary Population Report*, Sec. IVE, Table 1.

[10] Welles, Geo. M., and Others, "Soil Survey of Humphreys County, Tennessee." Manuscript, p. 142h.

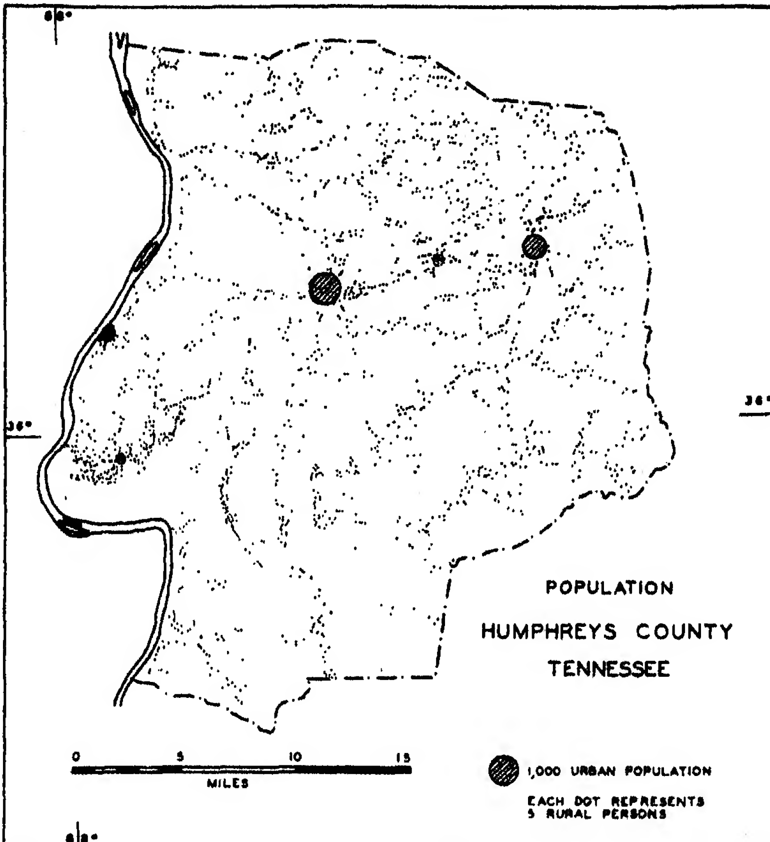

FIG. 5

(Source: United States Bureau of the Census, *Population of Tennessee, 1940.* Dots distributed according to planimetric maps of the Tennessee Valley Authority)

nessee Valley Authority studies [11] in the area indicate that only a small part of the timber is of saw-log size, and much is even below cordwood size. A too-rapid exploitation, failure to cull defective trees, and lack of forest-fire control have all been causes of the

[11] Tennessee Valley Authority, Dept. of Forestry Relations, Map of Forest Condition Classes, Humphreys County, Tenn. Knoxville, 1940.

decline in productivity from earlier times when the area had a thriving forest industry.

CURRENT PROBLEMS

The current problems of the county are: (1) increase of the average income of the farms with consequent reduction in the relief loads, (2) improvement of forest yields, (3) rendering of aid in the resettlement of farmers dispossessed of owned or rented lands by the creation of the reservoir, (4) provision of vocational training for the many young people who must continue to migrate from the county in the future, and (5) decrease of the cost of local government, which must be borne by fewer farms after the completion of the reservoir.

DIRECTION OF READJUSTMENTS

The major readjustments needed are the improvement of farming and forest practices and the inauguration of specific government services. In the detailed study of the Humphreys County Program Committee, in which the test-demonstration farm figures were used as a basis, it was estimated that 1,450 family-size farms "at an acceptable level of living" could be maintained in the county. In 1940 only 1,407 farms were reported, a figure that will be lowered by the emigration from the county of some farms from the bottoms that are to be flooded.

Improvement in farming consists in a shift of emphasis from grain farming to livestock, contour plowing, the planting of winter cover crops, the damming of gullies, and the fertilization of not only cropland but also pasture. The improvement of forest land includes fire protection, culling, and selective cutting. The planting of game birds will augment forest-land income in the future.

Perhaps the two most-needed government services are rural planning, which will prohibit the influx of settlers during the next economic depression, and a system of vocational training to enable young people to migrate more easily in the future.

OVERALL RECOMMENDATIONS

For specific recommendations the map of land classification (Fig. 6) is helpful. The land classified as nonfarmland (area No. 1) should be devoted to forest. Fire prevention and proper care and cutting should be practiced so that yields may increase. Further

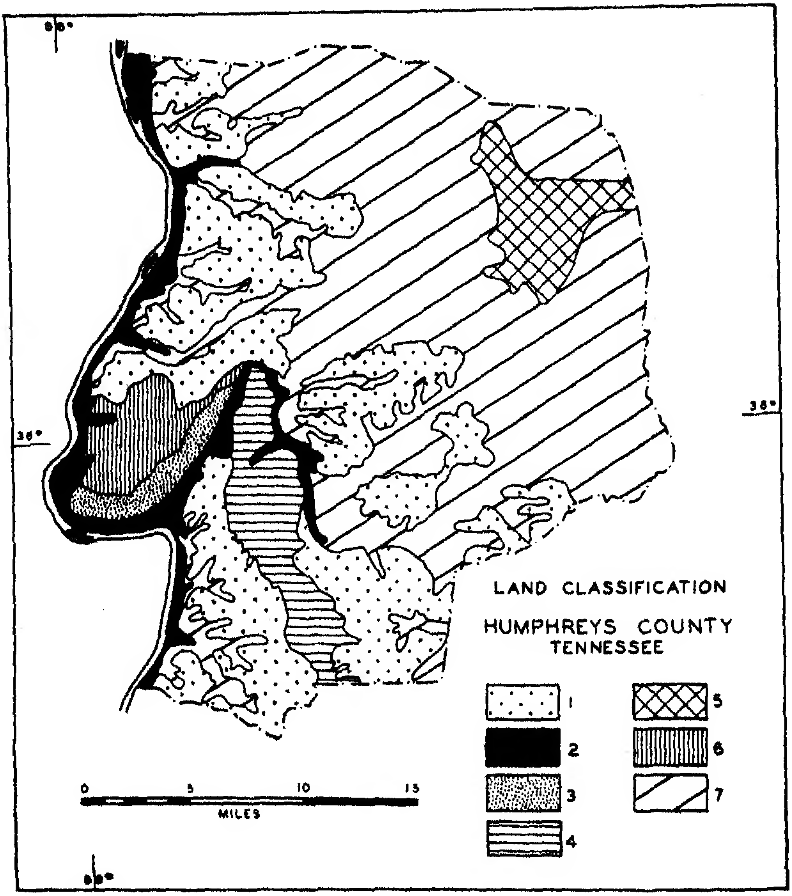

FIG. 6

KEY TO SYMBOLS

1. Land unsuited to agriculture
2. River-bottom lands to be flooded by Kentucky reservoir
3. River-bottom lands to be protected by proposed dikes
4. Buffalo River bottom lands
5. McEwen area
6. River-terrace area
7. Ridge-and-valley area

(Adapted from Humphreys County Program Planning Committee, "Land Use Classification of Humphreys County, Tennessee," manuscript, May, 1940)

study is needed to determine (1) whether national, state, or private control can best accomplish these ends, and (2), if accomplished by private control, whether a tax system such as the deferred timber tax recommended by the United States Forest Service might not be desirable. Reforestation by the Tennessee Valley Authority, especially near the reservoir, should continue. The landowners of the area that is to be flooded by the Tennessee Valley Authority reservoir (area No. 2) have been paid and are able to move and purchase new farms. The numerous tenants of this section constitute the chief problem, however. The proposed diked area (area No. 3), which will be leased by the Tennessee Valley Authority to former tenants, will provide a partial solution. Further recommendations are the continuance of Tennessee Valley Authority helped by maintaining an assistant in resettlement in the office of the county agency, and Farm Security Administration loans to encourage tenants to become farm owners elsewhere. The Buffalo River bottoms (area No. 4) will remain in cultivation and should have the continued aid of the Tennessee Valley Authority and the Tennessee Extension Service with test-demonstration farms. The major problem of this area seems to be the low farm incomes, largely resultant from improper farm practices. The McEwen Upland and the ridge-and-valley area (areas Nos. 5 and 7) should have greater emphasis placed upon forest land and pasture land to augment the income from the present cropland. State aid in forest-fire protection and in the test-demonstration farm program and from the Tennessee Valley Authority through its fertilizer distribution program is recommended. The possibility of establishing more factories such as those at McEwen for canning tomatoes and making cheese, to increase the farm income and provide additional employment, should be studied. Every possible aid and coöperation should be given the community study projects that cover the western part of these areas.[12] Many of the people on the river terrace (area No. 6) have rented land on the bottoms for crops. The proposed diked area will not be sufficient for their future needs. Aid from the Tennessee Valley Authority and the Farm Security Administration is necessary in order to relocate some of them.

An additional recommendation to the state would be a consti-

[12] A description of certain of these projects, in manuscript form, prepared by Mr. Clifton Goodlett, was made available to the author at the office of the county agent at Waverly, Tennessee.

tutional amendment enabling a consolidation of counties to allow a decrease in local tax burdens and an increase of services, especially aid in vocational training, which will be sorely needed in the future.

The local government could well continue the studies of recommended land use to the end of passing a zoning law that would curtail an increase in the number of farms during periods of economic depression.

PUBLIC WORKS RECOMMENDATIONS

There should be inaugurated a study of the needs for new roads and schools to fit the changed pattern of population that will be brought about by resettlement. It will be desirable to adjust the program as nearly as possible to provide additional work during the slack season in agriculture. Another recommendation would be to bring above substandard levels the 1,127 houses now in need of repairs. It is also suggested that a study of the possibilities of developing recreation along the proposed reservoir be made.

ACKNOWLEDGMENTS

The author is greatly indebted to many persons in Tennessee for information and help given, particularly to Mr. J. W. Moon, senior soil scientist at Knoxville; to Mr. H. A. Powers, of the Agricultural Relations Department of the Tennessee Valley Authority; to Mr. G. B. Shivery, extension forester; and the Messrs. Frank Joyce and H. S. Duncan, of the University of Tennessee Agricultural Extension Service; to Mr. W. M. Tolley, Humphreys county agent; to Messrs. Clifton Goodlett and Nathan Lowe, assistant agents; and to Miss Mattie Lee Fort, Humphreys County office of the Department of Public Welfare. Appreciation should also be expressed to Dr. Charles E. Kellogg, principal soil scientist, for his permission to use the generalized soil map of Humphreys County on which Figure 4 of this paper is based.

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GEOLOGY

NEW DRUMLIN AREAS IN CHEBOYGAN AND PRESQUE ISLE COUNTIES, MICHIGAN

STANARD G. BERGQUIST

IN A paper entitled "The Distribution of Drumlins in Michigan,"[1] presented before the Geology Section of the Michigan Academy in 1941, the author described in detail the various drumlin districts that were known in the state at that time. It was pointed out that new areas of distribution would undoubtedly be uncovered in other portions of Michigan when more thorough field work was carried on.

In the summer of 1941, through a coöperative project financed jointly by Michigan State College and the State Geological Survey, the writer, with the aid of two of his students, Dale Wallington and Robert C. Hannum, engaged in a rather extensive program of field investigation in Emmet, Cheboygan, and Presque Isle counties. Several new drumlin districts were located and carefully mapped (Fig. 1). Areas which previously had been only partially covered in reconnaissance were rechecked and brought up to date.

DRUMLINS EAST OF MULLET LAKE

Several small clusters of well-defined drumlins are centered near the rural towns of Aloha, Alverno, and Manning in Cheboygan County. They protrude through the sandy-clayey Algonquin lake plain in the region to the east of Mullet Lake and north of Black Lake. In this section they are undoubtedly cored in ground moraine that was deposited by the Huron ice lobe in its northeastwardly retreat across the area. The ice sheet that was responsible for the actual sculpturing of the drumlin forms moved into the district from the northwest, however, as is evidenced by the trends of the ridges.

The surface of the lacustrine plain in general ranges in elevation from 630 to 730 feet above sea level. The highest drumlins in the area

[1] Bergquist, S. G., "The Distribution of Drumlins in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 27 (1941): 451–464. 1942.

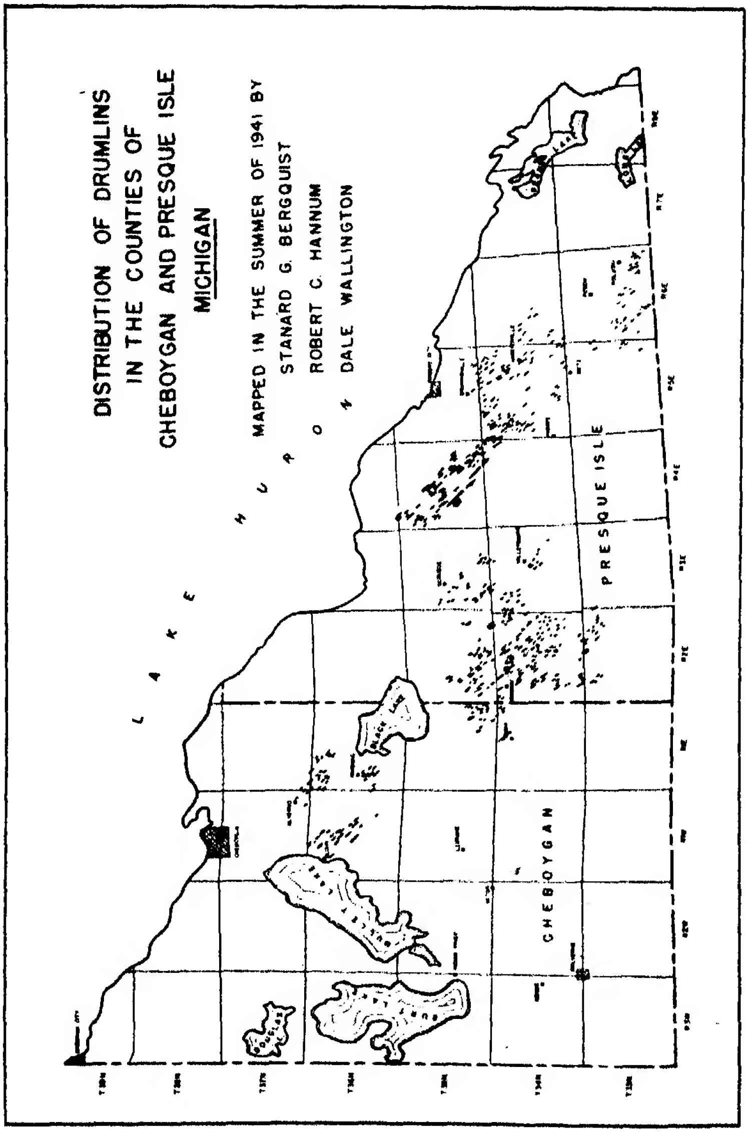
DISTRIBUTION OF DRUMLINS
IN THE COUNTIES OF
CHEBOYGAN AND PRESQUE ISLE
MICHIGAN
MAPPED IN THE SUMMER OF 1941 BY
STANARD G. BERGQUIST
ROBERT C. HANNUM
DALE WALLINGTON
LAKE HURON
PRESQUE ISLE
CHEBOYGAN

Fig. 1

attain an elevation of 735 feet, a height only five feet below the water plane of Lake Algonquin, whose shore is marked by features which stand at 740 feet. During the interval of occupation by the lake the drumlins were washed by its waters and subsequently smeared over with a thin coating of sediment deposited when the lake subsided.

A small pit, cut into a gravelly bar at an elevation of 685 feet, in the northeast quarter of Section 24, T. 36 N., R. 1 W., exposes five to seven feet of stratified material resting directly on unstratified boulder clay. Numerous erratics scattered promiscuously over the surface of the plain likewise seem to attest to a relatively thin coating of lacustrine wash over the till plain that supports the drumlin forms.

The drumlins of the district are relatively flat-topped and more or less symmetrical in outline. As a rule, both the nose ends and the tail ends of the ridges have slopes which are quite uniform. The absence of steepened stoss slopes may possibly be explained on the supposition that the forms were subdued by wave action during the occupancy of the area by Lake Algonquin.

The drumlins are arranged in parallel series, ranging in trend from S. 45° E. to S. 50° E. The ridges are somewhat low in relief, with crests seldom reaching more than forty feet above the level of the plain. The forms are relatively short, rarely exceeding half a mile in maximum length.

THE ONAWAY DRUMLIN DISTRICT

A comparative study of the map contained in this report with the one that accompanies the paper previously referred to will serve to reveal that the drumlin-till plain section has been greatly extended by field mapping during the field season of 1941. Altogether, several hundred individual drumlins were mapped out in the area included between the towns of Onaway, Ocqueoc, and Millersburg. Most of these forms are concentrated in the district to the south and east of Onaway in Presque Isle County. A small cluster is centered in the southeast corner of T. 35 N., R. 1 E., in Cheboygan County.

The till plain upon which the drumlins in this area are situated ranges in elevation from 860 feet in the north to 770 feet in the south. The plain is somewhat undulating in districts where drumlins are scarce or absent and definitely ridged where the forms are abundant. The boulder clay of the ground moraine is composed of the same type of material that comprises the drumlin ridges.

The drumlins of the Onaway district range in size from small features not more than twenty feet high and about an eighth of a mile long to well-defined ridges fifty and more feet high and up to a half mile in length. The ridges are best developed in areas where the drift is thick and where ample material was available for reworking by the advancing ice sheet. In localities where the drift is limited the features occur in the form of small, poorly developed drumlinoids. In such areas the drainage is haphazard, and vast tracts of swampy and marshy lowlands, responsive to a water table held close to the surface by the limestone floor, separate the till-plain drumlin areas. Where the rock pavement is exposed to the surface and the glacial till is absent or practically so, drumlins are missing altogether. There is no visible evidence that any of the drumlins in the region have been cut out of bedrock.

Glacial striae bearing S. 25° E. are present on the limestone surface in the region of Tower dam on the west edge of the drumlin district. These conform rather closely with the striae bearing S. 27° E. at the Marvin quarry south of Afton, which is some twelve miles to the west of the nearest drumlins at Onaway. Glacial markings bearing S. 32° E. are preserved on the rock pavement two miles directly north of the town of Onaway.

The long axes of the drumlins of the Onaway district range in direction from S. 35° E. to S. 45° E. Their trends, in general, are not in absolute harmony with the directional movement of the ice that produced the scorings in the rock pavement.

DRUMLIN DISTRICT NEAR ROGERS CITY

An extensive drumlin-till plain sets in at the northwest corner of T. 35 N., R. 4 E., and runs in a southeastwardly direction through the rural centers of Bruningville, Hagensville, Metz, Posen, and Polaski in Presque Isle County. On Leverett's map [3] this region is represented in part as a series of disconnected morainic islands separated from one another by areas of ground moraine. Field investigations carried on during the summer of 1941 revealed the presence of several hundred drumlins and drumlinoids widely dispersed

[3] Leverett, Frank, *Map of the Surface Formations of the Southern Peninsula of Michigan*, 1924. Published by the Geological Survey Division, Department of Conservation of Michigan, in Coöperation with the United States Geological Survey and the State Department of Agriculture.

over the plain, which stands at an elevation ranging from 760 to 860 feet above sea level.

In the northwest portion of the till plain, directly to the west and slightly north of Rogers City, is a grouping of well-defined drumlins with the long axes aligned in the general direction S. 45° E. The ridges are more or less symmetrical in outline, although there is a tendency in some of the larger forms to have stoss ends slightly steeper than the slopes on the lee. The drumlins in this section range from one-quarter to one and three-quarter miles in length and from twenty-five to sixty and more feet in height. They are grouped in parallel arrangement and are separated from one another by sags, which are fairly well drained.

Directly south of Rogers City, in the region extending from Bruningville through Metz, Posen, and Polaski, the drumlins are more widely dispersed in clusters, which are separated by marshy lowlands and swampy drainways. In this section they have trends that vary from S. 25° E. to S. 35° E. The forms are comparatively low and short, seldom obtaining a relief exceeding 35 feet or a length greater than three quarters of a mile. Many of the features, especially near the south end of the county, are poorly defined and assume the shape of drumlinoids. Here again the drift is thin and the drainage haphazard in development.

From Polaski the till plain continues southward into Alpena County, which was mapped out by Ver Wiebe.[8] Although his map shows no indication of drumlins on the plain I am certain that a detailed field study will reveal their presence there. Certain other areas in Alpena and adjacent counties may well be critically examined for possibilities of new drumlin localities and an extension of those which have already been mapped out merely in reconnaissance.

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[8] Ver Wiebe, W. A., *Geological Map Showing Surface Formation of Alpena County*, 1924. Department of Conservation of Michigan, Land Economic Survey and Geological Survey Coöperating.

STRATIGRAPHIC WORK IN NORTHERN MICHIGAN, 1933–1941

FREDRIK T. THWAITES

INTRODUCTION

SINCE the publication in 1934 of "Well Logs in the Northern Peninsula of Michigan Showing the Cambrian Section"[1] attempts have been made by the writer to clarify some of the tentative conclusions set forth therein. Various circumstances prevented the realization of more than a small fraction of the contemplated studies. In view of the complete halt in field work enforced by the war it seems fitting both to record the progress made and to outline the unsolved problems for the benefit of future students of the geology of a district to which it is possible the present writer may never return. Work which was accomplished included study of cuttings from several deep wells and visits to outcrops at Limestone Mountain, Munising, Menominee River, Jacobsville, and Freda.

REVISION OF THE CAMBRIAN AND LOWER ORDOVICIAN SECTION

Detailed work in Wisconsin by Raasch, Twenhofel, Wanenmacher, and the writer has demonstrated beyond serious question that the formation names "Mazomanie" and "Devils Lake" should be abandoned.[2] It has been established that the strata formerly

[1] Thwaites, F. T., "Well Logs in the Northern Peninsula of Michigan Showing the Cambrian Section," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 (1933): 413–426. 1934.

[2] Wanenmacher, J. M., Twenhofel, W. H., and Raasch, G. O., "The Paleozoic Strata of the Baraboo Area, Wisconsin," *Am. Journ. Sci.*, 228: 1–30. 1934.

Twenhofel, W. H., Raasch, G. O., and Thwaites, F. T., "Cambrian Strata of Wisconsin," Bull. Geol. Soc. Am., 46: 1702. 1935.

Raasch, G. O., "Paleozoic Strata of the Baraboo Area [Wisconsin]," *Guide Book, Ninth Annual Field Conference, The Kansas Geological Society*, pp. 405–414. 1935.

Newcombe, R. B., "Oil and Gas Fields of Michigan," *Mich. Geol. and Biol. Surv.*, Publ. 38, Geol. Ser. 32, pp. 21–29. 1933.

Wilmarth, M. Grace, "Lexicon of Geologic Names of the United States," *U. S. Geol. Surv.*, Bull. 896: 604–605, 1329. 1938.

ascribed to these formations belong within formations previously named. Beds formerly attributed to the "Mazomanie" are now recognized as part of the Franconia, and those of the "Devils Lake" are divided between Franconia and Trempealeau. The beds in Dickinson County which Ulrich placed in his "Devils Lake"[3] are very likely Franconia.

In view of the facts stated above the nomenclature used on the Centennial geologic map[4] needs revision. Another point of confusion on this map is the use of the name "Hermansville" as restricted to the same beds that were termed "Beekmantown" in the 1934 paper by the present author. This formation is the Prairie du Chien group of the U. S. Geological Survey,[5] still commonly known in Wisconsin by the time-honored name "Lower Magnesian." The name "Hermansville" was given by Van Hise and Bayley in 1900[6] and appears from their text to embrace all the strata which Rominger termed "Calciferous" and "Chazy,"[7] that is, both the Trempealeau and the Lower Magnesian. Just what type locality these authors had in mind is not clear from their brief description. In view of this uncertainty of definition the name "Hermansville" could very well be dropped. There are at least two fairly persistent sandstone horizons within the Prairie du Chien group of northern Michigan. For this reason any attempt to apply the threefold division into Oneota, New Richmond, and Shakopee (Willow River) formations, as has been done in western Wisconsin and Minnesota, would be unwise. In passing it may also be noted that the geologic columns given by Newcombe[8] are not in accord with the 1934 paper by the writer. Question may also be raised as to the division of the Prairie du Chien group into two systems, "Ozarkian" and "Canadian." Strong as is the evidence for a break in sedimentation prior to the

[3] Ulrich, E. O., and Resser, C. E., "The Cambrian of the Upper Mississippi Valley, Part II: Trilobites; Saukiinae," *Bulletin of the Public Museum of the City of Milwaukee*, 12: 217. 1933.

[4] Martin, Helen M., "The Centennial Geologic Map of the Northern Peninsula of Michigan," *Mich. Geol. and Biol. Surv.*, Publ. 39, Geol. Ser. 33. 1936.

[5] Wilmarth, *op. cit.*, pp. 944, 1490–1491, 1549–1550, 1694–1695, 2344.

[6] Van Hise, C. R., and Bayley, W. S., *U. S. Geol. Surv. Atlas, Menominee Special Folio*, No. 62: 11. 1900; Bailey, W. S., "The Menominee Iron-bearing District of Michigan," *U. S. Geol. Surv.*, Mon. 46: 494. 1904.

[7] Rominger, C., "Palaeozoic Rocks (Upper Peninsula)," *Geol. Surv. Mich.*, 1, Part III: 71–80. 1873.

[8] Newcombe, *op. cit.*, pp. 24, 26, 30.

deposition of the St. Peter sandstone, the writer has never been able to find any facts whatsoever in Michigan, Wisconsin, Minnesota, or Illinois which justify a systemic division within the Prairie du Chien.

ERRORS IN CENTENNIAL MAP OF MICHIGAN

Attention should be directed to certain errors in the Centennial geological map of Michigan. The strata exposed in the bed of the Menominee River at Grand Rapids are incorrectly mapped as "Black River." This correlation is not in accord with that of Rominger,[9] who gave a detailed section of twenty-one feet of obvious Prairie du Chien dolomite, most of which is now concealed by the power dam. The earlier correlation is checked by the log of the well at Stephenson. The mistake is evidently due to an attempt to join the map of Wisconsin prepared in 1912 by Hotchkiss and the present writer.[10] This map followed a manuscript map of Marinette County by Samuel Weidman. Another error is the mapping of Silver Mountain in T. 49 N., Rs. 35 and 36 W. as Paleozoic. Irving describes the rock in this hill as diabase,[11] probably of Keweenawan although possibly of Huronian age. So far as could be seen from a lake steamer, the Huron islands are not sandstone, as mapped, but a light-colored crystalline rock, probably granite. They are round knobs entirely unlike the forms developed on the sandstone of the mainland to the south.

RECORDS OF DEEP WELLS

The following records are based upon examination of samples by the writer, and include wells both in Michigan and in Wisconsin close to the state line. Well records are especially important in the eastern part of northern Michigan, where the low relief makes outcrops scarce and unsatisfactory.

[9] Rominger, *op. cit.*, p. 71.

[10] Hotchkiss, W. O., and Thwaites, F. T., "Map of Wisconsin Showing Geology and Roads," *Wis. Geol. and Nat. Hist. Surv.*, 1912.

[11] Irving, R. D., "Copper-bearing Rocks of Lake Superior," *U. S. Geol. Surv.*, Mon. 5: 202–203. 1883.

CHICAGO AND NORTH WESTERN RAILWAY CO. WELL, POWERS, MICHIGAN

(University of Wisconsin sample numbers 89676–89860)

Sec. 16, T. 38 N., R. 16 W.
Elevation 867.1

	Thickness in feet	Depth in feet
Drift, 52 feet		
Peat and muck	10	10
Sand, fine, gray, glacial	10	20
Till; gray, dolomitic	10	30
Clay, gray, dolomitic	10	40
Till, gray, stony	12	52
Prairie du Chien, 71 feet		
Dolomite, gray, some blue, residue sand, shale	23	75
Dolomite, light gray, sandy	5	80
Sandstone, very fine grained, light gray, dolomitic	5	85
Dolomite, light gray, sandy, some chert	15	100
Dolomite, light gray and pink, sandy, oölitic chert at bottom	23	123
Trempealeau, 119 feet		
Sandstone, very fine to medium-grained, light gray, dolomitic	2	125
Dolomite, light gray, fine sand	5	130
Dolomite, light gray, residue quartz silt	25	155
Dolomite, light gray, residue fine sand	40	195
Dolomite, light gray, residue sand, silt, glauconite	10	205
Dolomite, light gray, much sand, silt, glauconite	15	220
Dolomite, light gray, fine sand, silt, glauconite	22	242
Franconia, 143 feet		
Sandstone, medium- to fine-grained, light pink, dolomitic	23	265
Sandstone, fine-grained, light gray, dolomitic	40	305
Sandstone, medium- to fine-grained, light gray, dolomitic	20	325
Sandstone, medium to very fine grained, light gray, dolomitic	30	355
Sandstone, medium- to fine-grained, light gray, dolomitic	20	375
Sandstone, coarse- to fine-grained, light gray, dolomitic (Ironton member)	10	385
Dresbach, 18 feet		
Sandstone, medium- to fine-grained, white	18	403
Randville, 591 feet (beds inclined)		
Dolomite, light gray, residue quartz sand and silt with sericite	37	440
Dolomite, pink gray, residue quartz silt	20	460
Dolomite, light gray, residue silt and sand	75	535
Marble, dolomitic, light gray and pink, residue quartz silt	40	575
Dolomite, light gray, residue quartz silt	30	605
Marble, dolomitic, white to light gray, residue quartz silt	40	645
Dolomite, light gray to white, residue quartz silt, talc	349	994

Insoluble residues proved invaluable in examining these samples; not only did their study establish the base of the Prairie du Chien by the lowest oölitic chert but it also determined the pre-Cambrian age of the Randville dolomite by discovery of metamorphic minerals.

SOUTHERN KRAFT PAPER MILL WELL, MARINETTE, WISCONSIN

(University of Wisconsin sample numbers 97284–97349)

	Thickness in feet	Depth in feet
BLACK RIVER (PLATTEVILLE), 125 feet		
Dolomite, blue gray, some gray	93	93
No sample	12	105
Dolomite, blue gray and gray	20	125
PRAIRIE DU CHIEN, 350 feet		
Dolomite, light gray; chert, white	40	165
Dolomite, light gray	40	205
Sandstone, medium- to fine-grained, gray, dolomitic	10	215
Dolomite, light gray and black	10	225
Dolomite, light gray; shale, green gray; chert, white	30	255
Dolomite, light gray, scattered sand grains	10	265
Dolomite, light gray, some sand	30	295
Sandstone, medium-grained, light gray, very dolomitic	10	305
Dolomite, light gray	20	325
Dolomite, light gray, some scattered sand grains	30	355
Dolomite, light gray, pink, red	20	375
Dolomite, light gray	100	475
TREMPEALEAU, 40 feet		
Sandstone, very fine grained, pink, dolomitic	10	485
Sandstone, fine-grained, gray, very dolomitic, hard	30	515
FRANCONIA, 172 feet		
Sandstone, medium- to fine-grained, light gray	30	545
Sandstone, fine-grained, gray	20	565
Sandstone, fine- to medium-grained, gray	60	625
Sandstone, medium- to fine-grained, gray	10	635
Sandstone, fine- to medium-grained, gray, dolomitic	20	655
Sandstone, medium- to fine-grained, light gray	32	687
PRE-CAMBRIAN, 7 feet		
Granite, red	7	694

This record appears to show a considerably greater thickness of Prairie du Chien than was present in other wells in the vicinity. This may be due either to a difference in determination of the top or to a lateral variation in thickness.

WHITE HOUSE MILK CO. WELL, STEPHENSON, MICHIGAN

(University of Wisconsin sample numbers 98828–98907)

	Thickness in feet	Depth in feet
DRIFT, 38 feet		
Silt, sandy, yellow brown, very dolomitic	10	10
Sand, fine- to medium-grained, gray	10	20
Silt, light gray, very dolomitic	10	30
Till, many pebbles of dolomite	8	38
PRAIRIE DU CHIEN, 12 feet		
Dolomite, light gray; chert, gray, oölitic; sandstone, medium-grained, light gray; shale, gray, white, pink	12	50
TREMPEALEAU, 120 feet		
Dolomite, silty, light gray	95	145
Dolomite, silty, light gray, glauconitic	5	150
Dolomite, silty, pink, glauconitic	5	155
Dolomite, silty, gray, glauconitic	5	160
Dolomite, sandy, gray, pyritic	10	170
FRANCONIA, 140 feet		
Sandstone, fine-grained, gray, dolomitic	15	185
Sandstone, medium- to fine-grained, light gray, dolomitic	5	190
Sandstone, very fine grained, light gray, dolomitic	5	195
Sandstone, fine- to medium-grained, gray, dolomitic, hard	10	205
Siltstone, sandy, gray, dolomitic	5	210
Sandstone, medium- to fine-grained, light gray, dolomitic	25	235
Sandstone, fine- to medium-grained, light gray	10	245
Sandstone, fine- to medium-grained, light gray, dolomitic	5	250
Sandstone, medium- to coarse-grained, light gray, dolomitic (Ironton member?)	30	280
Sandstone, medium- to fine-grained, light gray	20	300
Sandstone, medium- to coarse-grained, light gray (Ironton member)	10	310
DRESBACH, 75 feet		
Sandstone, medium- to fine-grained, pink, light gray	15	325
Sandstone, fine- to medium-grained, light gray	25	350
Sandstone, medium- to coarse-grained, light gray	7	357
Siltstone, gray	3	360
Sandstone, medium- to coarse-grained, light gray	15	375
Sandstone, fine- to medium-grained, light gray	10	385
PRE-CAMBRIAN, 10 feet		
Granite, pink	10	395

The foregoing record demonstrates, as does that at Powers, the westward thinning of the Dresbach against the pre-Cambrian basement.

BADGER PAPER MILLS CO. WELL, PESHTIGO, WISCONSIN

(University of Wisconsin sample numbers 111791–111928)

	Thickness in feet	Depth in feet
DRIFT, 28 feet		
Sand, medium-grained, reddish brown	28	28
GALENA-PLATTEVILLE, 72 feet		
Dolomite, dark gray, blue streaks	17	45
Dolomite, dark blue gray	15	60
Dolomite, dark blue gray and light gray	10	70
Dolomite, light gray	15	85
Dolomite, light gray and dark gray	10	95
Dolomite, dark gray, some light gray	15	110
PRAIRIE DU CHIEN, 270 feet		
Dolomite, gray to light gray	20	130
Dolomite, light gray, some pink; sandstone, medium- to fine-grained, light gray	10	140
Dolomite, light gray, some dark gray	30	170
Dolomite, light gray; sandstone, coarse- to medium-grained, light gray	10	180
Dolomite, light gray	15	195
Dolomite, light gray; sandstone, coarse- to fine-grained, light gray	5	200
Shale, gray	5	205
Dolomite, light gray, sandy	20	225
Dolomite, light gray	35	260
Dolomite, light gray, some purple, sandy	5	265
Dolomite, light gray, sandy; chert, white, pink	15	280
Dolomite, light gray, some green gray	10	290
Dolomite, light gray; some chert, white	45	335
Dolomite, light gray; chert, white	10	345
Dolomite, light gray, residue sand, chert, glauconite	35	380
TREMPEALEAU, 40 feet		
Dolomite, gray, pink, silty, glauconitic	10	390
Dolomite, gray with black specks, silty	5	395
Dolomite, light gray, sandy, glauconitic	2	397
Sandstone, fine-grained, light gray	3	400
Dolomite, light gray, sandy	20	420
FRANCONIA, 85 feet		
Sandstone, medium- to fine-grained, light gray, dolomitic	20	440
Sandstone, medium- to fine-grained, gray, dolomitic (no sample, 450–455)	25	465
Sandstone, fine- to medium-grained, light gray, dolomitic	10	475
Sandstone, medium- to coarse-grained, light gray, dolomitic (Ironton member?)	15	490
Sandstone, medium- to fine-grained, light gray	10	500

	Thickness in feet	Depth in feet
FRANCONIA, 85 feet (*Concluded*)		
Sandstone, coarse- to medium-grained, light gray (Ironton member)	5	505
DRESBACH, 200 feet		
Sandstone, medium- to fine-grained, light gray	50	555
Sandstone, fine-grained, light gray	10	565
Sandstone, medium- to fine-grained, light gray	65	630
Sandstone, fine-grained, light gray	10	640
Sandstone, medium- to fine-grained, light gray	25	665
Sandstone, fine-grained, light gray	10	675
Sandstone, medium- to fine-grained, light gray	30	705
PRE-CAMBRIAN, 3 feet		
Granite, red, decomposed	3	708

The close agreement of this record with that of a shallower well given in the paper of 1934 is noteworthy.

LIMESTONE MOUNTAIN AND VICINITY

The writer spent three days at Limestone Mountain in 1935 in company with Josiah Bridge of the United States Geological Survey, G. O. Raasch, then of the University of Wisconsin, and C. A. Bays, at that time a student at the same institution. Most of the exposures were visited and extensive fossil collections were made. A map, the basis of Figure 1, was prepared. The excellent account by Case and Robinson [12] was used as a guide. These authors say: "The dips in the uppermost of all the exposures show a remarkable diversity although there seems to be quite generally a dip toward the center of the outlier in each case. There is no suggestion of folding" (p. 176). They also state: "In our opinion these outliers have been broken both by major faults, which involve the sandstone below, and by minor faults or breaks, the result of erosional forces" (p. 181). Although dips were recorded on the map their cross section displays horizontal strata. Grading for a ski slide and close examination of the topography along the section shown in Figure 1 convinced the writer's party that disturbance of the strata is not confined to slumped blocks. There is a considerable area of vertical strata which have been eroded into a series of small hogbacks. This

[12] Case, E. C., and Robinson, W. I., "The Geology of Limestone Mountain and Sherman Hill in Houghton County, Michigan," *Mich. Geol. and Biol. Surv.*, Publ. 18, Geol. Ser. 15, pp. 165–181. 1915.

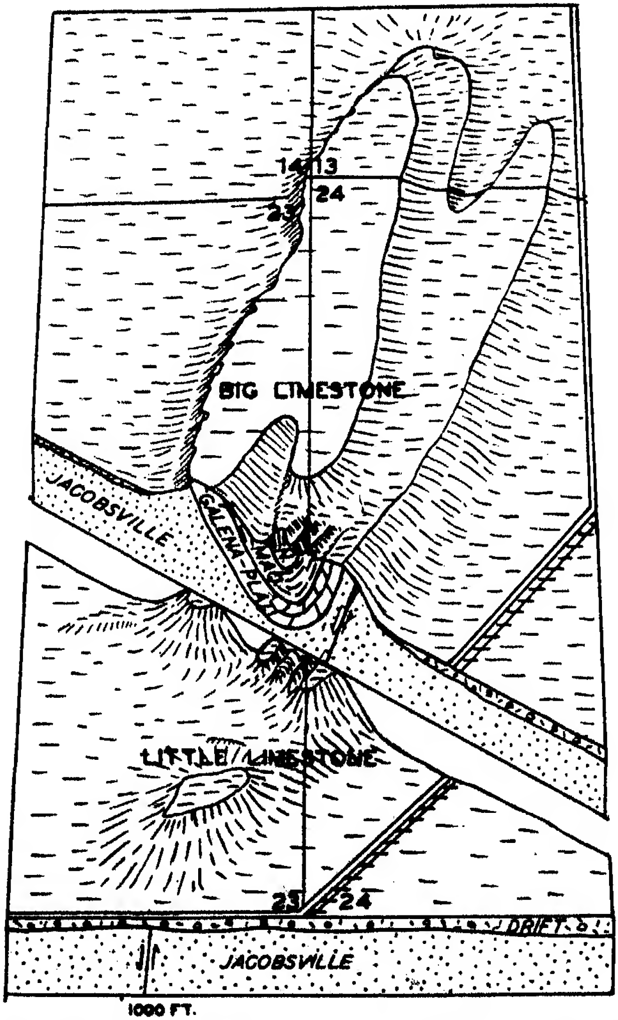

FIG. 1. Block diagram of Limestone Mountain, T. 51 N., R. 35 W., Michigan. Drawn from sketch by C. A. Bays, 1935

structure may be drag along a major fault on the east side of the hill, as indicated in the block diagram. On the south the strata of Little Limestone are much less disturbed and appear to be faulted against the vertical beds. On account of the drift cover the structure of the northern part of Big Limestone is not so clear. East and southeast of Big Limestone road cuts disclose dips up to 35 degrees, with both northeast and northwest strikes. Silver Mountain, several miles to the south, was not visited, but its form strongly suggests a tilted fault block with a dip slope on the northwest.

The sandstone which immediately underlies the Black River dolomite of Limestone Mountain was found to be in large part fine-grained and apparently dolomitic. It is probably the Glenwood member of the Platteville dolomite. Farther from the dolomite contact the sandstone is coarser and shows the irregular coloration, the confused bedding, and the pebble zones which are characteristic of the Bayfield group of sandstones of Wisconsin.[13] The relation of this sandstone to the strata at the type locality of the Jacobsville sandstone farther north is not clear. Similar rock is also exposed east of Limestone Mountain along the shores of Keweenaw Bay. At L'Anse the Jacobsville rests unconformably on the Huronian.[14] The red and light-gray sandstone at Jacobsville is somewhat more quartzose and even-bedded than is common in the Bayfield group and slightly suggests the Devils Island formation of Wisconsin. It is stated that geophysical measurements indicate that it is only about 1,100 feet in thickness and much less in the vicinity of Limestone Mountain.[15] However, a well at Lake Linden did not reach the bottom at 1,502 feet.[16]

RELATION OF JACOBSVILLE SANDSTONE TO MIDDLE KEWEENAWAN TRAP

For many years the outcrops of sandstone in the northeastern part of T. 46 N., R. 41 W., have been cited to demonstrate an unconformity between horizontal Lake Superior sandstone and tilted

[13] Thwaites, F. T., "Sandstones of the Wisconsin Coast of Lake Superior," *Wis. Geol. and Nat. Hist. Surv.*, Bull. 25: 25–47. 1912.

[14] Personal communication from S. A. Tyler.

[15] Hotchkiss, W. O., Rooney, W. J., and Fisher, James, "Earth-Resistivity Measurements in the Lake Superior Copper Country," *Am. Inst. Min. and Met. Eng.*, Tech. Publ. No. 32. 1928.

[16] Smith, R. A., "Results of Deep Borings," Part III, *Mich. Geol. and Biol. Surv.*, Publ. 24, Geol. Ser. 20, p. 222. 1917.

Middle Keweenawan traps.[17] However, Allen and Barrett report on the authority of Seaman's field notes that sandstone in Sections 11 and 14, about a mile west of the locality in Section 13 described by Pumpelly and Irving, is intruded by diabase.[18] The dip of the Keweenawan flows in this locality is only a few degrees to the north, and a faint northerly dip is recorded in the sandstone of Section 13. These facts strongly suggest that the sandstone is all Lower Keweenawan and that it has no connection with the problem of the Jacobsville sandstone. Certainly the burden of proof is now upon anyone who correlates this sandstone as Jacobsville.

It has long been known that the contact of the Jacobsville sandstone with the traps on Keweenaw Point is a thrust fault. This structure was described in detail by Irving and Chamberlin, who concluded that there has only been a slight amount of movement since the deposition of the sandstone, which they ascribed to the Cambrian.[19] The fault is exactly similar to that of northwestern Wisconsin described by the present writer.[20] In both localities the thickness of sandstone beds upturned by the thrust is several thousand feet, which demonstrates a considerable post-sandstone movement. The fact that conglomerate is confined to the vicinity of the fault is probably explained by other faults within the sandstone. It is true that there is débris from the Middle Keweenawan in these conglomerates, but similar débris is also present in all the sedimentary layers within the Middle Keweenawan itself. The dips of the sandstone toward the fault, which caused certain early geologists to conclude that the sandstone is older than the traps, may be overturned layers, as the writer proved on Middle River, Wisconsin.[21]

CAUSE OF THE KEWEENAW FAULT

One of the most striking features of the Middle Keweenawan traps is their localization with practically no outliers. Does it not seem plausible to conclude that they originated in a sinking basin

[17] Pumpelly, Raphael, "Copper District," Part II of *Upper Peninsula, 1869–1873, Geol. Surv. Mich.*, 1, Part II: 4. 1873; Irving, *op. cit.*, pp. 202–203.

[18] Allen, R. C., and Barrett, L. P., "Contributions to the Pre-Cambrian Geology of Northern Michigan and Wisconsin," *Mich. Geol. and Biol. Surv.*, Publ. 18, Geol. Ser. 15, pp. 83–84. 1915.

[19] Irving, R. D., and Chamberlin, T. C., "Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior," *U. S. Geol. Surv.*, Bull. 23. 1885.

[20] Thwaites, *op. cit.*, pp. 75–87 (see note 13).

[21] *Ibid.*, pp. 66–69, 76, 90.

bounded in part by fault scarps? The original setting would then be quite similar to that of the basalts of the Columbia Plateau. It is noteworthy that much of the border of the traps is along faults, for instance, from Douglas County, Wisconsin southwest, as well as parts of the southeastern border in Wisconsin. Only locally do these faults pass within the area of flows. The writer suggests that the Keweenaw Point fault was initiated by an older fault scarp along which the flows were either bordered or at least much reduced in thickness. Much of the faulting may be the result of settling, with only a moderate amount of crustal shortening. It is clear that trap occurs under the sandstone as far east as Silver Mountain, but that the border of the flows is concealed farther to the north.[22]

AGE OF THE KEWEENAW FAULT

One of the objections of the early geologists to extensive post-sandstone movement on the Keweenaw fault was the vast amount of erosion since the major movement. If we correlate the Jacobsville with the Bayfield group of Wisconsin, however, this erosion is recognized as the "Great Denudation" which led to the pre-Cambrian peneplain. It does not follow that all movement is post-Jacobsville. The quartzose nature of the Bayfield sandstones proves that by the time of their deposition much of the traps had been overlapped and buried, so that débris came chiefly from the pre-Keweenawan rocks.[23] The age of deformation at Limestone Mountain casts little light on this problem. The complex down-dropped structure of the mountain is not parallel to the thrust fault and is more closely allied to the local disturbances recorded at several localities in the Mississippi Valley,[24] for instance, at Des Plaines, Illinois, and Glover Bluff, Wisconsin. Although many of these structures have been termed "cryptovolcanic," there is no positive evidence of igneous intrusion in any of them. Limestone Mountain appears to be located close to or above the eastern border of the flows under the Jacobsville sandstone,

[22] Thwaites, F. T., "Post-Conference Day No. 2, Monday, September 2, 1935," *Guide Book, Ninth Annual Field Conference, The Kansas Geological Society*, pp. 221–228. 1935.

[23] Thwaites, *op. cit.*, pp. 100–109 (see note 13). Tyler, S. A., Marsden, R. W., Grout, F. F., and Thiel, G. A., "Studies of the Lake Superior Pre-Cambrian by Accessory-Mineral Methods," *Bull. Geol. Soc. Am.*, 51 : 1469–1482. 1940.

[24] Thwaites, F. T., "Stratigraphy and Geologic Structure of Northern Illinois," *Illinois Geol. Surv.*, Rep. Invest. 13 : 42. 1927.

and it is quite possible that this explains the faulting. It is also probable that there was movement on the Keweenaw fault at the same time.

VICINITY OF MUNISING

The geology of the vicinity of Munising was studied in considerable detail by Bergquist.[25] The writer visited Munising in 1938, and compared the exposures with both subsurface data and the Wisconsin column. Typical siltstone of the Lodi member of the Trempealeau was found in the road to Miners Castle high above the base of the "Hermansville." It is clear that the glauconitic and pyritic dolomite of Au Train Falls is Trempealeau and not Prairie du Chien. The contact traced by Bergquist is the division between the Franconia and the Trempealeau and not the base of the "Ozarkian," as he supposed. This correlation is followed in Figure 2.

No line of division into Franconia and Dresbach could be found in the sandstones which make up the Pictured Rocks. It is evident, therefore, that the type locality of the Munising sandstone embraces only the Franconia of Wisconsin and that the underlying formations have pinched out south of Munising, as shown in Figure 2. The base of the Franconia is about ten feet of conglomerate, with pebbles of quartz and quartzite, which lies on irregularly bedded arkosic sandstone.[26] This underlying sandstone is Jacobsville and closely resembles the Bayfield sandstone of Wisconsin. It is highly improbable that it is a lateral change in the Dresbach, which is evenly bedded, light-colored, and clearly marine.

Figure 2 correlates what is known of the relations of the Jacobsville to the overlying marine deposits. The northern section strongly

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Ekern, G. L., and Thwaites, F. T., "The Glover Bluff Structure, a Disturbed Area in the Paleozoics of Wisconsin," *Trans. Wis. Acad. Sci., Arts, and Letters*, 25: 89–97. 1930.

Bucher, W. H., "Cryptovolcanic Structures in the United States," *Internat. Geol. Congr.*, XIV Sess. 2: 1055–1084. 1936.

Bastin, E. S., "Contributions to a Knowledge of the Lead and Zinc Deposits of the Mississippi Valley Region," *Geol. Soc. Am.*, Special Papers 24: 71–103. 1939.

Shrock, R. R., "Stratigraphy and Structure of the Area of Disturbed Ordovician Rocks near Kentland, Indiana," *Am. Mid. Nat.*, 18: 471–531. 1937.

[25] Bergquist, S. G., "The Occurrence of Glauconite in the Hermansville Formation of Alger County, Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 12 (1929): 231–237. 1930; and "The Cambrian-Ozarkian Contact in Alger County, Michigan," *ibid.*, 22 (1936): 421–435. 1937.

[26] Thwaites, *op. cit.*, p. 426 (see note 1).

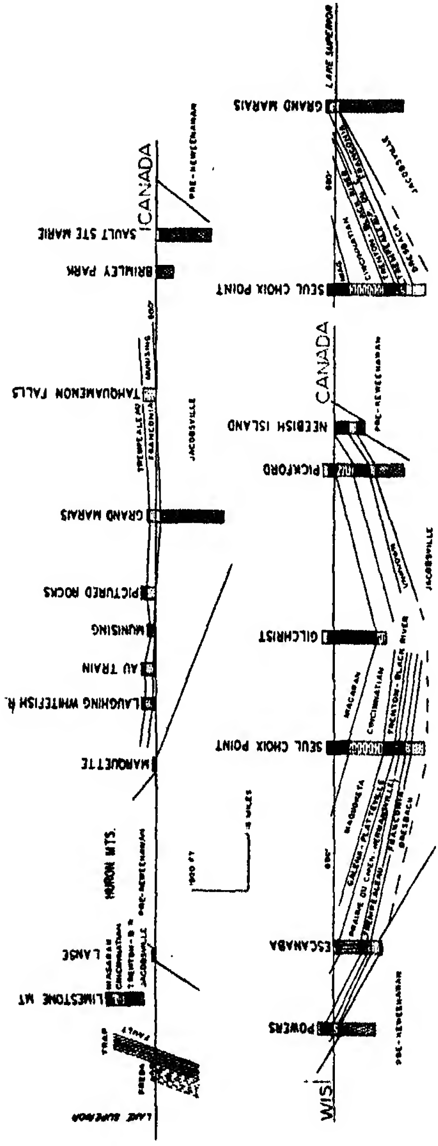

FIG. 2. Diagrammatic sections of northern Michigan from Limestone Mountain to Sault Ste Marie; from Powers to Neebish Island; and from Seul Choix Point to Grand Marais. Well records are connected to show correlation, not details of structure, between them

suggests that these younger beds overlapped unconformably a tilted and base-leveled nonmarine sequence, the Jacobsville. In the southern section the Paleozoic strata are so much more disturbed that the unconformable relation is not clearly demonstrated. Near the eastern side of Michigan the succession is not the same as that at Munising. Instead, the Jacobsville is separated from the Black River by a light-colored sandstone of unknown age.[27] At Limestone Mountain sandstone occurs directly below the Black River. These facts suggest progressive overlap of the Paleozoic strata on a pre-Cambrian basement which was not wholly crystallines but included the Jacobsville.

CONCLUSIONS AND UNSOLVED PROBLEMS

The conclusions reached by the author from information available to him at the date of writing this paper are summarized below:

1. The original Munising sandstone is the Franconia of Wisconsin.
2. The age of the Jacobsville sandstone is not yet established, but is quite likely Upper Keweenawan; it is probably a nonmarine deposit.
3. Faulting has been recurrent throughout the district; the Keweenaw and the Limestone Mountain faults may be related to pre-Keweenawan displacements which bounded the Middle Keweenawan flows.
4. Much movement has taken place on these faults since the deposition of the Jacobsville, and the denudation of the upthrust areas is apparently an event of pre-Cambrian time; the last movement, however, was post-Silurian.
5. The Jacobsville sandstone overlapped the traps because disturbance went on during its deposition.
6. The Paleozoic formations overlapped the Jacobsville from the south, progressively thinning out around the northern end of the Michigan basin.
7. The term "Hermansville" apparently included both Trempealeau and Prairie du Chien and is so poorly defined that it should be abandoned.

[27] Smith, R. A., "The Occurrence of Oil and Gas in Michigan," *Mich. Geol. and Biol. Surv.*, Publ. 14, Geol. Ser. 11, pp. 243–244 (Neebish well). 1914.

8. The sandstone which the older geologists thought unconformable on the Middle Keweenawan flows of the South Range may be Lower Keweenawan.

Although the writer hopes that he may return to this long-neglected district, this is uncertain and should not stand in the way of anyone else who wishes to finish the work he began; if the suggestions here given prove of value in guiding such research they will have fulfilled their purpose.

It must be recognized that the foregoing summary presents more unsolved problems than definitely established facts.

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ANTHROPOLOGY

THE ARCHAEOLOGY AND GEOLOGY OF TWO EARLY SITES NEAR KILLARNEY, ONTARIO

EMERSON F. GREENMAN AND GEORGE M. STANLEY

INTRODUCTION

SINCE 1938 five sites for which a chronology has been established by their connection with raised beaches of Lake Huron have been found in the Manitoulin District of Ontario. Three have been described in some detail by the present authors (8–9). Of the two sites forming the subject of this paper the one first discovered is briefly described by the senior author in *Man*, 1941 (7); a digest of a paper that he gave at the Minneapolis meeting of the American Anthropological Association in May, 1941, appears in the *Notebook of the Society for American Archaeology* for August, 1941. These five sites are situated in the Frazer Bay region, north of the east end of Manitoulin Island.[1] Four of them are on the mainland within six miles of one another. The fifth is on Cloche Channel, an arm of Frazer Bay, fifteen miles to the west. The work here reported, which is part of an extensive survey of the Manitoulin District, has been made possible by grants from the Horace H. Rackham School of Graduate Studies. The present paper is a preliminary statement.

ARCHAEOLOGY

Of the five datable sites discovered on the shores of Frazer Bay and its offshoot, Lansdowne Channel, one was completely excavated in 1938, and the remainder are in a state of partial excavation. The first one is on Great Cloche Island, on the west side of Frazer Bay; it consisted of a small hearth covered by beach materials, at an elevation of 608 feet[2] (8). The four other sites are within two to six

[1] See Map 351 A, Canada Department of Mines and Resources, Mines and Geology Branch. The Bay Finn referred to in the text of this paper is called "Narrow Bay" on this map. Lansdowne Channel, not designated on the map, parallels Badgeley Point on the south.

[2] The elevations given are above sea level. The elevation above the level

miles northeast of Killarney (Fig. 1). They have been designated by symbols indicating the names of geographical features, such as KB-1, CH-1 (9), and GL-1, 2 (George Lake Sites 1 and 2). George Lake is seven miles east of Killarney, and it was during a trip from that lake to the east end of Bay Finn in August, 1940, that site GL-1 was discovered. It is on a gravel beach at an elevation of 877 feet, about two miles inland. The beach (Fig. 2, Sections 1F, 1G)

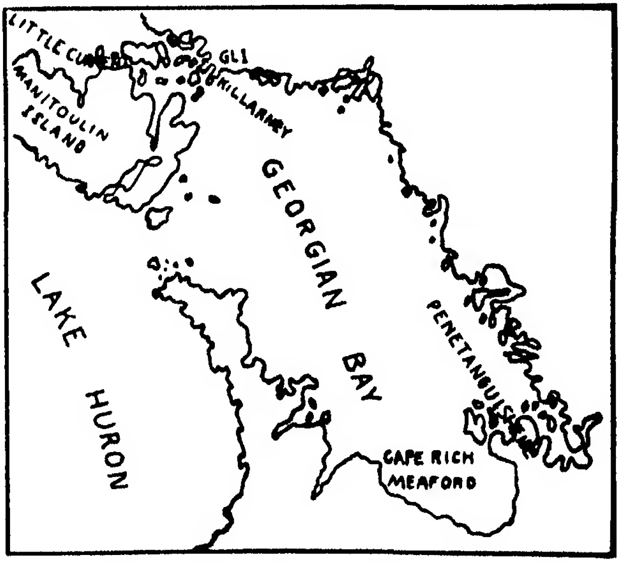

FIG. 1. Georgian Bay, Ontario Site GL-2 is about half a mile from GL-1

lies between two quartzite knobs and is some 500 feet long east and west, sloping from its crest southward about 300 feet to the brow of a gully that is evidently due to surface drainage since the formation of the beach. The beach proper appears to be about 100 feet wide, with its crest 20 feet from its northern border. It is at the top of a deposit of gravel and sand of undetermined thickness that partially fills the small valley between the two quartzite knobs, and has as its southern border the shore of a small lake known locally

of Lake Huron is obtained by subtracting 580 feet. The exact elevation of the surface of Lake Huron above sea level in July, 1939, was taken as 579.7 feet by the United States Lake Survey Office in Detroit.

FIG. 2. The sites of GL–1 (at 1 F–G) and GL–2 (at 1 A), looking north at GL–1. A dense growth of trees in each valley is not shown in this sketch

as Lake Lumsden, about a mile long and half a mile wide. The distance from the crest of the beach to the shore of Lake Lumsden is about 800 feet.

Half a mile southwest of GL–1 is another site, GL–2, which was discovered during the season of 1941. Here artifacts of quartzite of the same types as those from GL–1 were found on the surface of a small, rather indistinct beach at elevations of 880 to 905 feet. The measurements were taken with a defective hand level and are subject to correction. The beach of GL–2 (Fig. 2, Section 1 A) is likewise part of a valley fill of gravel and sand, which slopes down to the shore of Lake Lumsden and through which a gully has been cut.

When GL–1 was first found quartzite flakes were strewn on the surface of the beach in considerable profusion, and a dozen or more artifacts, broken and complete, were collected. The débris of occupation was most in evidence for 350 feet westward from its eastern end. The remaining western portion does not seem to have been occupied. In the first ten days of excavation this site was taken to be a workshop, since the implements were all of one material and since that material, quartzite, was available in the immediate vicinity; in addition, the implements, which were large and roughly flaked, corresponded to the forms usually known as "blanks" (2; 10). Only halves of semilunar knives were found at first, and though this type of implement had not been previously discovered in the Manitoulin District, the presence of a new type could not be certified for the region, since the semilunarity of the whole specimen was not clear from the half. It was not until worn or rolled specimens were found that it was realized that the implements and flakes were in all probability contemporaneous with the waters of Lake Huron when they were at a level 297 feet higher than they are at present and that a complex not previously known in the region was being investigated.

From the surface to a depth of about two and one-half feet the beach is composed of heavy gravel, with some stones as much as 0.8 foot in diameter but averaging about 0.2 foot. Farther down there is a succession of strata of stones of various sizes, and coarse sand. Artifacts (including flakes) occur from the surface to a depth of approximately 1.5 feet. Some several inches long and large flakes and quarry blocks are found at a depth of 1.0 foot, but the

vertical measurements strongly suggest that those in the deeper part of the artifact zone are very small flakes that may have worked down from high levels by movements of the beach, although it has not been demonstrated that they would work downward rather than upward. At the present stage of investigation of this site speculations concerning the manner in which artifacts were covered by one or more feet of gravel are fruitless because of the variety of forces that have shifted the materials of the beach to that depth.

GL–1 was a quarry workshop, and probably a village or a camp site in addition if the results of a soil analysis taken in 1941 are confirmed by a second analysis now in process. In the first, made by Mr. Robert Prasil, a student in the Department of Anthropology, it was indicated that fine white claylike material adhering to most of the flakes, and occurring on the surface of the beach to a depth of a foot or more, contained a higher phosphate content than could have been derived from the rocks of the region. Bone is the only possible source of this chemical in such amounts. This type of analysis has already been applied by O. Arrhenius in Sweden (see 1; 20).

The typology offers little to confirm or to disprove the use of the site for domestic purposes. Most of the implements are broken, and though many are to be regarded as finished forms, they may have been fractured just before completion. Three flakes have been replaced in their original positions on two implements, and not one was found more than ten feet from the implement. But both specimens are blanks, and it seems significant that the attempt to replace flakes on finished implements has met with no success; they would naturally be carried away from the spot where they were made. Parts of six implements have been fitted together, but no two parts of a single specimen were more than fifteen feet from each other.

TYPOLOGY

The industry represented at GL–1 is typologically distinct from others found after four seasons in the Manitoulin District in an area about 180 miles long and 50 miles wide. The implements fall into six classes; in no class are there fewer than two specimens, and no material other than quartzite was used, though other materials, except flint, are present in the form of glacial boulders.

Semilunar Blades

The semilunar blades range in length from 11.3 cm. to 18 cm., in thickness from 15 mm. to 3 cm., but one blank is 4 cm. thick. This blank and a complete specimen indicate a type of blade with one edge fairly straight and the opposite edge deeply curved and with one end pointed and the other end rounded. Some are planoconvex. There is a definite tendency for the thickest portion of the implement to be closer to the straight than to the curved edge. The edges of most specimens are irregular jagged lines formed by large flake scars reaching a considerable distance inward. Flaking is very coarse for the most part, but three blades have been retouched along the edges, and two of these are much thinner than the rest from the site. These two are evidently halves, perhaps of other than semilunar types. They might be flakes, both faces of which have been trimmed down.

To date five complete semilunar blades have been found (including one blank). There are eight that are nearly complete, one of which may also be a blank. Thirty-three fragments represent both ends and mid-portions; one of them may be another blank. It is much worn on the faces and edges and also over the edges of the broken end (Pl. I B). In outline the semilunar blades are akin to the implements called "side-scrapers" by Burkitt (3, p. 71), from the European palaeolithic period. In Burkitt's opinion the convexity of one edge is clearly an essential feature, and he regards the type as purposely adapted to the scraping of skins.

Choppers

The choppers are triangular or oval-pointed, with straight or rounded bases. The range in length is from 11 to 19 cm. and in width from 8 to 10 cm. At least one, the largest, is probably a blank. A face of one specimen is a single-flake surface, but the opposite face comes to a peak. This is the only chopper that is planoconvex. The edges of these implements are coarsely flaked like those of the semilunar blades, and although the outlines suggest the hand axes of the European palaeolithic, there is no twist (i.e. the edges do not traverse the longitudinal cross section diagonally from base to point). One chopper, the smallest, has near the point four flake scars that may be the result of pressure rather than percussion. In addition to a large fragment, which may be a basal portion of an implement,

there are five choppers; another piece found south of the beach at a lower elevation may be a fragment of an implement of this type. It has been lightly retouched along the basal half of one edge.

Ovate Blades

The term "ovate" is here given to a blade type that is similar in outline to the choppers but smaller, ranging in length from 8.5 to 14 cm. (Pl. I O, P). One is planoconvex in cross section, the flat side being a fracture plane. Another is apparently a reject. Still another is elliptical in outline, with the widest part a little to one side of the center. The chief characteristics of these implements are their narrowness, as compared with the width of the choppers, and the evident importance of the point. One of them with the basal end missing (unless the implement is complete as it is) is retouched around the point on one face, most of the remaining portion of which is a fracture plane. Plate I P has something of the appearance of an implement to be used in the hand as a dagger. Some of the specimens classed as fragments of semilunar blades may be points of implements of this type.

Quadrangular Blades

Eight of the thirteen quadrangular blades terminate at one end in a thick face at a right angle to the true faces, and may be only portions of blades. They range in length from 5.5 to 12 cm. (Pl. I D). One face of the longest consists of a single flake scar with a bulb. The ends of two that are better made than the rest are thin and more rounded. These are the only ones showing retouching at the edges. Both have the break at one end, and may be portions of ovate blades. It seems likely that these implements are knives or scrapers with outlines adapted to some particular purpose. Two other specimens classed under this head have outlines like those of some of the semilunar blades. One is shown as Plate I H. The small size of these two specimens forbids their classification as semilunar blades.

Retouched Flakes

Two retouched flakes are illustrated in Plate I M, N. There are at least three implements of this type, two with triangular outlines and one with a rectangular outline. All three are retouched on one

side of one edge. On three spalls that fit one with a triangular outline the edge is continued in line, but the retouching stops.

Perforators

The designation perforators seems to be the only suitable one for four specimens. Two could scarcely have been used in any other way (Pl. I J, K). The third could have been used as a small knife (Pl. I, I). The two smaller ones are quartzite slivers 2.4 and 3 cm. long and 8 and 12 mm. wide. The shorter tool, which has retouching on only one edge of one face, is planoconvex in cross section. The longer is retouched over at least three quarters of its surface, and is elliptical in cross section. The third specimen (Pl. I, I) is 7 mm. thick, with coarse flaking on both faces. The cross section is angularly elliptical. Another specimen of nearly the same proportions, perhaps retouched but without a point, resembles the "channel flakes" from the Lindenmeier site (12, pl. 4, lower right-hand corner).

Other Objects

There is a much-worn specimen that may be a scraper of the beaked type combined with a point to make it a multiple tool of the scraper-graver type like those reported from the Lindenmeier site (12, pl. 13h). The scraper edge and the point both have facets that could be of artificial origin, but its rolled condition leaves the matter in some doubt.

A large core was found on the surface about 500 feet south of the beach on the second terrace (Fig. 2, Section 3D). It is nearly square, being 15 by 13 cm., and is planoconvex. The plane surface, the inner (flake) surface, has coarse flake scars throughout the perimeter; at the central portion there is a broad flat area with a partly detached bulb. The striking platform has been trimmed off. A more typically Levalloisian tortoise core, about half as large, was found on the beach (Pl. I F). The coarse flakes were removed from the outer surface instead of from the flake surface, which is unaltered. This specimen is worn on all the edges and ridges.

Flakes

Several thousand flakes were collected within five-foot horizontal sections at intervals of 0.2 foot, beginning with the surface. The largest are as much as 15 cm. long, and the majority have more than

two faces. Primary flakes, apparently detached by indirect percussion (6, pp. 27–29), are most numerous. The impression gained by examination of a large number is that they are squamous in appearance; on the average they are 4 cm. in both length and width, with a thickness of 4 mm. below the bulb. The platforms are very small and bulbs are weak. Bulbar scars and concentric ridges are rare.[3] The average platform, estimated to be about 1 cm. long and 5 mm. wide, is elliptical, mostly faceted; whether as a result of a blow or from intentional preparation cannot be said. Shatter marks are absent or invisible. Outer surfaces of most specimens are faceted. The lower edge (that opposite the platform) of a great many is broken; it consists of a narrow face and is curved in cross section in a direction opposite from that characteristic of a hinge fracture (i.e. it has the convexity toward the outer surface of the flake). But some of these edges are angular or flat in cross section.

The angle formed by the platform and the main flake surface is estimated to be from 90 to 100 degrees[4] in about 99 per cent of the material. Some flakes have a retroversion of the upper (bulbar) portion with the bulb set to one side of the central axis. They have much higher platform angles.

Large thin symmetrical flakes also have high platform angles. On eight of these that are from 5 to 12 cm. long the angle runs from 110 to 122 degrees. The one with the highest angle is a utilized flake, triangular in outline, with each face forming a single flake scar and with retouching along one edge (Pl. I N). The platform was struck three times before the flake was detached, as is indicated by that number of incipient cones of percussion. The platforms of these eight flakes are unfaceted. Another flake of this type is the Levalloisian tortoise core already mentioned, the unfaceted platform of which is at an angle of 135 degrees to the main flake surface. A single shatter mark indicates but one blow.

Dependence of the GL–1 people upon quartzite as material for the manufacture of implements, and perhaps a long acquaintance with it, are suggested by a comparison of their flakes with those

[3] In the literature on stone techniques quartzite materials have been described (if at all) in terms of flint, and though the quality of the two materials is similar, quartzite is less firm in texture and the effects of percussion are more diffused, with the result that the typical lithic landmarks are less pronounced.

[4] Not "a little less than 90 degrees," as was erroneously stated by the senior author in *Man*, 1941 (7).

from KB–1, a Woodland site six miles away at an elevation of 608 feet (9). Flint was available to the occupants of KB–1 within two miles. It was abundantly and expertly used, whereas all but one of the quartzite implements are poorly made, being relatively thick with outlines that are not well controlled. Thin primary flakes of quartzite are very rare, which suggests that implements were roughed out by detaching small blocks and slivers in a clumsy way, to be followed directly by attempts at retouching along the edges. The refuse of this quartzite industry is made up of very small flakes, splinters and small blocks with three or more faces. The quartzite implements are all small, being chiefly projectile points up to 5 cm. long and 1 to 3 cm. wide. The KB–1 quartzite is inferior to that of GL–1, as is indicated by the presence of a reddish tinge that is absent from the upper portions of the quartzite ranges in the Killarney area.[5] At CH–1 the large squamous primary flakes are present, indicating a relationship on this point to GL–1 rather than to KB–1. Flint is found only in the topsoil at CH–1. Though the quartzite here was probably secured from higher levels, some of it is reddish. It is a little inferior to that used at GL–1 but superior in firmness of texture to that used at KB–1. The CH–1 and GL–1 people quarried large blocks and made large implements. The KB–1 people seem to have contented themselves with smaller pieces detached by erosion, and the implements they made were smaller.

No utilized material other than quartzite has been found on or in connection with GL–1. Apparently flint was not available in the region when the waters of Lake Huron were at the level of this beach, and other glacially transported materials were not used. None of the implements shows evidence of intentional grinding. No large hammerstones are found, probably because quartzite blocks of almost every size and shape lie around in profusion, having been detached from the main masses by erosion. The site yields no pottery or bone material, and so far no evidence of hearths or of dwellings has been seen either on the beach itself or on the quartzite hills around it.

Portions of seven artifacts and one large flake have been collected from GL–2, half a mile to the west of GL–1 and at an elevation of ten to thirty feet higher. Five of the fragments are parts of semi-

[5] Map 221 A (Collins Inlet Sheet), Canada Department of Mines, Geological Survey.

lunar blades or choppers. Three are planoconvex in cross section. The sixth is either half of a semilunar blade or an ovate blade of the same type as those described for GL–1. The seventh comes from a blade of undeterminate type or a narrow flake with one short cutting edge (Pl. I L). This edge, 4 cm. long, has four parallel narrow flake scars that are so shallow and delicate that the pressure technique is implied. The opposite edge is a flat surface 1 cm. in width. The material from GL–2 is all quartzite. This site was first found in the summer of 1941, and no systematic excavations have yet been undertaken. It is very difficult of access and is covered with thick underbrush.

TRANSPORTATION OF ARTIFACTS BY SURFACE WATERS

Implements and flakes are found on the surface between both GL–1 and GL–2 and the shores of the small lake (Lake Lumsden) to the south and east in areas 5 A, 6 A, 5 D–E, 6 D–E, 7 D–E of Figure 2. This condition was at first regarded as possibly a result of the spread of cultural materials as the occupants followed the receding shore line, but investigation suggests surface drainage as the cause.

Between GL–1 and the shore of Lake Lumsden there are two terraces, the surfaces of which are about 20 feet below the top of the beach proper (3 D, 4 C of Fig. 2). Apparently they are remnants of the sloping valley fill at the top of which the beach lies. They are notched by two deep V-shaped gullies. A few flakes and one of the two tortoise cores were found on the top of one of these terraces. Between the bases of the terraces and the shore of Lake Lumsden artifacts and flakes occur on the sandy surface, 75 to 85 feet lower than the crest of the beach where the main site lies. The two implements discovered at this lower level are typologically the same as those on the beach, and there is no sign of refuse material such as one would expect if this area was the camp site, at the shore of the lake, and if the site on the beach was merely the quarry workshop. The surface of this area is channeled throughout with shallow ditches and small watercourses, sinuous and branching, and it is at the edges and on the banks of these channels, which are dry during most of the field season, that artifacts and flakes are found. The water that cut these small channels came largely from the two gullies separating the terraces, and since the slope is very gradual in this area the heavy volume of water in the deep gullies was spread out, and in times of

flood the whole area is probably one shallow freshet, moving to Lake Lumsden rapidly in some places and slowly in others. Under these conditions it seems obvious that the flakes and artifacts of this lower level were derived from the tops of the terraces and from points nearer the beach itself, and they show the results of transportation in the small fracture scars on the faces and broken edges. None of the implements so far found in this position have the heavily rolled appearance of those from the beach.

Artifacts have been collected close to flakes on this lower level, but none of them fit together to indicate that manufacture took place on the spot. In the summer of 1941, when this condition was first observed, most of the flakes were left *in situ*, and were numbered and photographed in order that any movement might be noted in the season of 1942. It is certain that the amount of water coming down this slope through the two gullies from the level of the beach and from a large area to the north of and above the beach is very considerable in the spring. This condition was approximated after an abnormally heavy rain in the season of 1941.

The situation at GL–2 is identical, except that in it there is but one gully, about 20 feet deep in its upper portions and extending from the top of the valley fill down to within 300 feet of Lake Lumsden, where, as at GL–1, the waters divide into innumerable small distributaries owing to the low gradient. There are a few flakes in this area, and one half of a semilunar blade, or the base of a chopper, found in the bottom of the gully adjacent to the site proper shows abundantly on its faces and edges the effects of battering. These transported materials from the two sites approach to within about 500 feet of one another, whereas the sites themselves are nearly half a mile apart.

There is no possibility that Lake Lumsden has ever been high enough to reach either beach. The whole valley that contains the lake is open to the southwest at a level about 25 feet above it, whereas the sites begin at 60 feet to 70 feet higher.

PATINA

Many of the artifacts and flakes from both sites are patinated (13). The color, which is brown, extends in from the surface to undetermined depths, probably not solidly from one face to another. It is sometimes darker on one face than on the other. There is an apparent

correlation between patina and the presence or the absence of water wear or the degree of water wear. The color is identical with the iron oxide stain in the mixed sand and gravel of the beach one foot below the surface and on downward. In addition to this patina, about fifty per cent of the artifacts and flakes exhibit a glaze ranging from small specks to areas two or three centimeters across. The specks, which may occur at any place on the specimen, cannot be regarded as the result of use, since they are found on unworked pebbles of quartzite on the beach and on blocks of quartzite beyond the beach. They may be attributed to abrasion caused by soil flow and other movements of the beach through the action of frost and vegetation. The evidence for this interpretation can be clearly seen with a hand lens, which reveals the glaze at the tops of the minute irregularities of the surface, whereas the depressions between them are unglazed. The glazed areas are minutely striated. Most of the glazing is on flaked surfaces, probably unrelated to rounding, and unquestionably was acquired after the manufacture of the implements.

CHRONOLOGY

The situation of GL–1 with respect to the topography of the area is consistent with the view that the cultural materials belong to a period when the waters of the Great Lakes were at that level. At that time and from that level up to the level of Lake Algonquin (about 188 feet higher at GL–1) the coast in this area was a very rugged one formed by quartzite cliffs with ragged indentations and small rocky islands. The GL–1 beach, however, was in a doubly favored situation at the bottom of a bay about a mile from the main shore line and at the water front of a broad valley, access to which was easy from the beach. If the cultural materials at GL–2 are also contemporary with the lakes at that level, the beach of GL–1 was under water, provided the measurements taken in 1941 are not too far off. An evident preference for soil rather than a rock surface as a place to live is seen in the choice of these two sites. They are the largest level spaces of drift materials that have yet been observed in the area at their levels. From a view of the country over a radius of some forty miles, seen from the highest peak, it is apparent that at the time of their occupation these two sites were on a long narrow peninsula extending westward from the mainland.

The contemporaneity of the cultural materials of GL–1 with

Lake Huron at that level is a deduction based entirely upon the worn condition of eleven artifacts, a considerable number of flakes, and one tortoise core. The implements comprise seven semilunar blades, two choppers, one ovate blade, and the scraper-graver, which may be entirely of natural origin. The tortoise core and eight of the artifacts are heavily worn on both faces and edges. It is scarcely conceivable that this condition would result from use, since some wearing occurs only on parts other than the edges and points and since by-products such as flakes and the tortoise core also exhibit the worn condition. It is also unlikely that it resulted from a desire to produce a ground implement because no fully ground implement was made and because one half of a semilunar blade is worn over the broken edge (Pl. I B). It does not seem likely that chemical action could be responsible. Alkaline solutions will attack and reduce quartzite under high temperatures (4, p. 478), and although GL–1 has been the scene of forest fires, the soil is not highly alkaline, and but a small proportion of the cultural materials lying on the surface are worn, some of them only on small areas.

Wave action is the sole explanation that fits the facts. Implements and by-products of their manufacture exhibit various degrees of wearing; they are found on a beach that was formed by the waters of the Great Lakes and that was the scene of violent wave action; the materials of the beach are large enough and heavy enough to do the grinding, which is similar to that on other raised beaches in the Great Lakes region comparable in duration of water action. It is frequently by such worn and rounded pebbles that abandoned beaches are first recognized.

The results of the action of water on artifacts are seen on two other sites in the Killarney area, and there is a marked correlation between the materials of the beaches of the three sites and the nature and the degree of the wearing. At KB–1 the beach material is almost entirely sand; only potsherds are worn. At CH–1 the beach, at an elevation of 636 feet, is composed of sand in one portion, of heavy gravel and large stones in another. Some artifacts of quartzite found in the former position are delicately but unmistakably worn, and quartzite flakes from the latter area that are believed to be of human origin are heavily worn. The occurrence of waterworn quartzite artifacts at CH–1, though similar ones are not observed at KB–1, would seem to be a result of the difference in the intensity

of wave action. CH–1 has two components, that in the subsoil, believed to be contemporaneous with Lake Huron at that level, and that in the topsoil (also possibly contemporaneous), where flint and slate occur in addition to quartzite. KB–1 was occupied during the descent from Lake Nipissing (unless pottery and certain forms in stone have a much higher antiquity than is currently believed); it is possible that at CH–1 the subsoil component was laid down before the rise of water to the Nipissing beach, and it may be mentioned that this component has yielded a part of a blade the outline of which recalls the semilunar blades of GL–1. Thus the artifacts in the CH–1 subsoil component, if they were in place previous to the Nipissing Great Lakes, were subjected to wave action longer than those of KB–1, for the site was awash three times. The topsoil component of CH–1, although nonceramic (the site is nonceramic), is more closely related to KB–1 than it is to the subsoil component directly beneath.

There is a striking correlation in the degree of patina of the objects from GL–1 and the subsoil component of CH–1 on the one hand and KB–1 on the other. None of the quartzites from KB–1 show it; the majority of those at CH–1 are heavily patinated. At GL–1 some are heavily patinated, but most of the material in the upper foot of the site is white and fresh in appearance. It lies in the zone of pure white substance that is like clay in its texture. The beach of CH–1 is brown sand throughout, with strata of gravel of the same color. Glazed areas occur only on the artifacts at GL–1. If the cause of the glaze as given above is correct, its production would be mechanically nearly impossible at KB–1 and in the part of the CH–1 beach that is composed of sand.

At KB–1 and CH–1 artifacts are in and beneath strata that were formed by water. The condition is clearer at KB–1, where some of the strata consist of fine gravel and where the artifacts could not have been placed beneath their upper surfaces by excavation from the surface without the obvious displacement of strata. At CH–1 no excavations from the surface account for the presence of artifacts in the subsoil, but none lie beneath gravel strata. The evidence for contemporaneity here consists chiefly in the distribution of the flakes in conformity to the surface by water action and in the wearing of some of the specimens. At GL–1 cultural materials are found to a depth of 1.5 feet, and it is entirely possible that they were buried

by the action of water, but this cannot be demonstrated at present. Stratigraphical conditions indicate no other cause, though the type of soil is not such that signs of excavations from the surface would be long maintained.

The belief in the contemporaneity of the cultural materials at GL–1 is based in the final analysis upon the presence of waterworn implements. The existence of another similar site close by (GL–2) at a somewhat higher level goes far to substantiate the high antiquity of both sites. It suggests that more will be found at this general level in the immediate region or elsewhere in the area of the postglacial tilt. It is noteworthy that these two sites are on the edge of what was once a geographical barrier some hundreds of miles long, the northern shore of a late Algonquin stage of the Great Lakes, and that the industry has never been observed south of that shore line.

CULTURAL RELATIONSHIPS

There are hints of a relationship between this complex and the Folsom. Channel flakes and scraper-gravers have already been mentioned in this connection, and to these traits may be added the semilunar blades. Dr. Frank Roberts has stated in correspondence that blades of this type are in the collection from the Lindenmeier site, and a portion of one is shown in the report (12, pl. 14m). Another fragment, differing from the GL–1 semilunar blades in being under 5 mm. thick (material chalcedony), was found on the Clovis site (11, pl. 29).

Roughly flaked blades of quartzite, schist, and chalcedony with semilunar outlines have been recorded from four other sites, two of which are on raised beaches. One of the beaches is at Tadoussac, at the junction of the St. Lawrence and Saguenay rivers in Quebec (14; 22), and the other is at Windy Tickle, near Hopedale, Labrador (21, pl. 4g, h). The presence of projectile points at the latter site, small lozenge-shaped forms (21, pl. 4n–s), is in agreement with the supposition that this site is later than GL–1, if Labrador was beneath the ice sheet when GL–1 was occupied. At the two other sites heavy quartzite choppers and blades have been found, but the semilunarity is less evident. One, excavated by Mr. Douglas Byers and Mr. Frederick Johnson for Phillips Academy, is at East Killingly, Connecticut, and the other is on the shore of a small lake in Alberta,

where Dr. Donald Leechman of the National Museum of Canada collected a few specimens in 1940.

GEOLOGY

GEOLOGICAL RELATIONS OF THE BEACH AT SITE GL–1

Though estimates of the age of the Nipissing beach are accepted as reasonably approximate, they are much less satisfactory for earlier stages of the Great Lakes. Perhaps extensive varve studies may sometime furnish fairly reliable dates for the earlier lakes and a much-desired improved calendar of the postglacial. At present it seems futile to give figures in so many thousands of years for the age of the beach at Site GL–1, since much leeway would be necessary and its limits would be uncertain. A fair picture of the geological events during and since the formation of this beach will show, however, that it has a far greater antiquity than is demonstrable for previous archaeological finds about the Great Lakes. And since knowledge of the ancient shore lines in the Killarney region is scanty, we must start elsewhere to present the matter.

Ancient Beaches in Southern Georgian Bay

The Algonquin and Nipissing are the strongest, most heavily developed, and most widely registered of all ancient shore lines in Georgian Bay and northern Lakes Huron and Michigan. There are also many weaker beaches that, though more difficult to identify from place to place, are highly important in the interpretation of the sequence of events and the passage of time. Some critical results derived from studies in southern Georgian Bay (16; 17) are presented in Table I.

The names of the beaches are listed in Table I in the order of their formation. In the second column are given the elevations of the principal ancient beaches found at Cape Rich, less than ten miles north of Meaford. In the third column are the vertical distances of each of these below the Algonquin, as derived by subtraction from the second column. In the fourth column are figures for slopes of the beaches as determined in the region of Penetanguishene. All the ancient beaches rise toward the north-northeast in consequence of the broad postglacial uplift of northeastern North America, a movement that reached from southern Michigan to Hudson Bay and from Winnipeg to Newfoundland.

TABLE I

CRITICAL RELATIONSHIPS OF ALGONQUIN AND LATER BEACHES IN SOUTHERN GEORGIAN BAY

Beach	Elevation in feet above sea level	Vertical distances below Algonquin	Tilt in feet per mile
Algonquin	801	0	3.38
Upper Algonquin group	801–762	0–39	...
Lower Algonquin group			
Wyebridge	718	83	undetermined
Penetang	684	117	3.00
Cedar Point	663	138	2.875
Payette	624	177	2.75
------------------	?	?	?
(hiatus, with perhaps several later stages?)	?	?	?
------------------	?	?	?
Nipissing	635	166	0.42
Post-Nipissing	635–580	166–221	...
Lake Huron	580	221	0.00

The upper Algonquin group comprises a series of closely spaced beaches and covers a vertical interval of about forty feet at Cape Rich. The Algonquin beach, the uppermost of the group, was formed when the discharge of Lake Algonquin was diverted southward past Port Huron by uplifting of the Trent valley outlet. The lower beaches in the group were formed successively as continued uplift was bringing land above water, and the Port Huron outlet maintained Lake Algonquin at a fairly constant level.

There is an interval in which beaches are lacking below the upper Algonquin group, and it signifies a relatively swift lowering in lake level, during which waves could not make good shore forms. This seems to be due to the abandonment of the Port Huron outlet as glacial retreat freed a lower channel toward the Ottawa valley. At the Wyebridge stage the lake level stabilized on some outlet long enough for good beaches to form, though the water must have fluctuated somewhat, as it does seasonally in our present lakes. At Cape Rich a series of beaches with a vertical range of twelve feet belongs to the Wyebridge stage; the principal and strongest beach is at the top. The Penetang, Cedar Point, and Payette stages are similarly represented, each by a short group of beaches at some

places, or by a single strong beach at others, separated from the beaches of preceding or succeeding stages by a considerable barren interval in which beaches are absent.

An inspection of the tilts listed in Table I shows that a nearly parallel relation exists between the Algonquin and the lower Algonquin water planes. Only a minor amount of tilting took place between the Algonquin and Payette stages; very much more came later, although most of it antedated the Nipissing beach, which has a very gentle slope in comparison with the others. In view of the fact that the major share of the uplift of the Algonquin beach occurred in the interval between the formation of the Payette and Nipissing beaches, it may be inferred that this interval was a long one, perhaps several times longer than the post-Nipissing, which is generally estimated at about four thousand years. Yet to assign ages to all the beaches in proportion to tilt would involve an unwarranted assumption that tilting has gone on at a constant rate. Indeed, other considerations imply that the rate of uplift has decreased toward present time.

After the Payette stage the lake dropped to successively lower levels as new channels toward the Ottawa became available, and ultimately an extreme low was reached with the use of the Mattawa valley at North Bay. Thereafter only postglacial tilting was to modify the lakes, and as the North Bay outlet region was elevated it brought about rise of water and encroachment on the shore everywhere to the south. The south end of the lake reached and submerged the lower Algonquin shore lines one after another in a sequence the reverse of that in which they were formed. When the Port Huron outlet was attained and southerly discharge ensued again, the lake level came to the comparatively stable position that it has maintained since. It was during this transfer of outlet that the Nipissing beach was formed. The post-Nipissing series beneath it developed during the latest period of uplift. The post-Nipissing beaches bear exactly the same relation to the Nipissing beach as does the upper Algonquin group to the Algonquin beach. In some localities they comprise more than twenty individual beaches, but, regardless of number, the series covers the entire interval between the Nipissing and the present shore.

The Payette water plane was submerged by the Nipissing at Cape Rich. But northeast from there Algonquin and lower Al-

gonquin planes together rise rapidly and draw away from the Nipissing; in the widening gap appear additional beaches not represented to the south.

Shore Lines on Manitoulin Island

Studies on Manitoulin Island have identified the Algonquin and Nipissing beaches very well, but have not been detailed enough to correlate satisfactorily the lower Algonquin members with those in southern Georgian Bay. When this becomes possible, more definite interpretations can be made for Site GL–1 at Killarney. Of value for the present purpose is an Algonquin beach at 1,012 feet elevation on the brow of the high Niagaran escarpment about three miles south of Little Current. Its slope here is four to five feet per mile, which is somewhat steeper than it is farther south.

TABLE II

Anticipated Elevations of Beaches at Locality A, Killarney

Beach	*Elevation in feet above sea level*	*Vertical distance below Algonquin*
Algonquin	1,060	0
Wyebridge	965	95
Penetang	914	146
Cedar Point	883	177
Payette	835	230

An attempt can be made to project water planes north to Killarney and anticipate elevations for them there. A point is arbitrarily selected on the south slope of the Killarney hills a mile north of the head of Lamorandière Bay and some three miles north and a little east of Killarney village (this is Locality A; see p. 525). The point is about nine to twelve miles north along the tilt line (depending on its exact direction) from the 1,012-foot Algonquin beach near Little Current. The projected Algonquin water plane might be expected here at an elevation of about 1,060 feet, and lower Algonquin beaches might be expected below it at intervals that are greater than those given in Table I in proportion to their respective divergent slopes. These expected elevations are given in Table II, but it must be remembered that they are only hypothetical and are subject to such corrections as more abundant work in the near vicinity, a thing much desired, may eventually bring about.

Shore Line Measurements near Killarney

The hills around Killarney are somewhat hostile to investigation of the ancient beaches; they are predominantly of very resistant rock and are thickly wooded and untraveled. So far only the Nipissing shore line can be definitely identified. The two best representatives of it that have been discovered in the vicinity and measured are (1) a well-formed terrace and bluff, elevation 663 feet, on the Tyson farm, less than a mile east of Chickanising Creek, and (2) a bar of well-rounded quartzite pebbles, elevation 667–668 feet, stretching for about 400 feet across the valley of a little creek at John Proulx's cabin and sugarbush, one mile northwest of the east end of Frazer Bay.

Levels were also run from Lake Huron to some of the higher beaches that have been found at a few places by searching among the hills. They are here described by localities, with elevations in feet above sea level.

1. Locality A, North Slope of Killarney Hills within One Mile North of Lamorandière Bay

The geological features will be listed as they occur along the old Conley trail, about one-eighth mile west of the telephone line, starting northward from the bay: indefinite or weak beaches at elevations of 665, 744, and 771 feet; definite little beaches near trail by cliff at 839 and 842; a succession of beach ridges, the strongest being one of well-rounded quartzite pebbles that extends 250 feet south-southwest from cliff across trail to outlying rock knob, elevation 874–873; progressively weaker beaches below this at 869 and 866 and above it at 875, 878, 886, and 892; a rounded-pebble beach at 903, 75 feet long from cliff out to rock knob; trail turns northeast along base of cliffs, passing scattered little beaches or banks of rounded gravel against cliffs at 905, 908, 914, 916, 912, and 922; trail next passes over the two ridges of a double tombolo constructed southward from cliff to outlying rock ledges; west arm at 917 composed of well-rounded small quartzite pebbles; good beach of cobble and pebble at 921 along base of cliff overlooking this; trail dips down 15 feet after leaving 917 beach, then rises up over east arm of tombolo, which diminishes in elevation from 916 to 913 in its length of about 120 feet south from cliff and consists of very well

rounded cobbles of quartzite; there is another marked ridge east of it at 914 and then a series of weaker beaches on eastward slope at 908, 905, and 886; at base of this slope Conley trail meets Killarney telephone line by creek, and telephone line crosses a little gravel beach at 892, 60 feet out from cliff; farther from cliff and immediately east of telephone line and creek is a strong gravel beach at 876 with an east-northeast trend; a shorter and weaker beach behind it at 878. To the north up the cliff and on the next "flat" two weak beaches were noted at 1,027 and 1,032, a little east of telephone line; their materials are very poorly rounded and assorted, so that they are much less striking than most of the lower beaches listed, but they are the highest beaches found near Killarney. Therefore one may doubt that a highest Algonquin beach was registered on the Killarney hills.

2. Locality B, Northeast End of Lumsden Lake at Site GL–1

The main beach, about 500 feet long and at an elevation of 876 feet, has already been described. Another beach was found about 1,000 feet south of the site and immediately south of a low quartzite knob; it is about 60 feet long across a small draw leading toward Lumsden Lake, composed of very well rounded quartzite pebbles, and at an elevation of 873. Locality B is about one and one-fourth miles north along the tilt line from Locality A.

3. Locality C, on Portage Trail from George Lake to Whiterock Lake

The trail crosses faint beaches at 737, 746, 758, 759, and 760 feet, a better beach of rounded pebbles at 775, strong ridges of rounded pebbles and rubble at 791, 792, and 794; a faint beach at 807; broad gravel ridge at 810 on extensive flat, by cabin in sugarbush; back of flat at boulder-strewn rise at 814; boulder-covered benches at 835 and 855. The summit of the portage is a strong gravel bar at 883–882 extending 300 feet southwest from trail to rock ledges; south from southwest end of bar are good beaches at 878 and 873, bench at 839 cut into slope, broad gravelly flat at 812; just north of the summit a distinct bench at 878, and farther along trail a bench at 835 below steep 30-foot bluff; overlooking the 883-foot bar and just northeast of the summit of the trail is a poorly developed bench at 887. Locality C is about three miles north along tilt line from Locality A.

DISCUSSION AND RELATIONSHIPS

Even in favorable regions two or three localities could scarcely afford a complete picture of the entire succession of beaches because recognizable features have a habit of occurring only in the occasional spots favored by topography and a supply of beach materials. Yet the fact that outstanding beaches appeared in the 870–885-foot interval at all three of the localities described is one satisfying item of correspondence. Moreover, the difference between the strong beaches, 873 feet at A, and 883 feet at C, is quite commensurate with the three miles' distance (along tilt line) between them and a slope of about three feet per mile. From Table II this shore line would seem a likely correlative of the Cedar Point, but since this is not sure and since there is a rather definite selectivity of wave action at that level, we might give it a temporary name for future reference, "Chickanising beach," after the creek draining George Lake, about which it lies. There are good beaches at about 915 feet at Locality A that may correlate with the Penetang stage. Nothing striking was found to match with the Payette and nothing at all for the Wyebridge. But some post-Payette stage is indicated by the good beaches at 796–792 feet at Locality C.

The highest shore features found near Killarney (1,032, 1,027 feet) are certainly too low to belong to the highest Algonquin shore line, and they are surprisingly weak even for any of the lower beaches of the upper Algonquin group. Two days were spent in looking for beaches higher on the hills, but without results. A few "perched boulders" found at elevations of 1,200 to 1,350 feet on some of the higher slopes and summits prove that the lake never reached this level. They were released by melting of the glacier that brought them, and came to rest in unstable positions on the bare rock slopes, perhaps supported by a few smaller stones. Storm waves or winter ice would surely have dislodged them and toppled them downward had the postglacial lake ever been so high. Such perched boulders are a common sight along the coasts of Labrador (5) and Hudson Bay (18) above the highest limits of the postglacial sea. Tracing them downward to their lowest limit furnishes another means of approximating the highest water level; but at Killarney the boulders were not sufficiently numerous to give this method much promise. Search for the highest Algonquin beach elsewhere along the "north shore,"

north of Great Cloche Island, has likewise been fruitless (15). There are indications, too, that the Algonquin shore line ran out northward against glacial ice not far north of Goulais, near the southeast corner of Lake Superior (19). It seems most probable, therefore, that the Killarney hills were still covered or obstructed by ice while the Algonquin beach was being registered a few miles farther south. This has an interesting bearing on the environment of the people who fashioned the artifacts at Site GL–1.

A train of geological events may now be reconstructed. The locus of Site GL–1, where no beach yet existed, was uncovered by the retreating glacier or by outlying masses of ice after the Algonquin beach had been abandoned, probably before the lake had dropped to the Penetang stage. This locus was then covered by water instead of ice. The lake dropped to the Chickanising stage (Cedar Point?) and good beaches were developed at Site GL–1 and near by. During this stage artifacts were left on the surface of the beach, and some of them were rounded by wave action before the waters withdrew farther. Wave working of the artifacts may have been accomplished within a period of a few centuries or a thousand years after the abandonment of the Algonquin beach and while the ice front was but 50 or 100 miles distant, for the glacier still occupied the east coast of Lake Superior and the Mattawa Valley. The lake continued to drop to lower levels until it was probably more than 300 feet, perhaps over 400 feet, below Site GL–1. A long period of tilting and slowly rising water brought the lake back to the Nipissing beach, 208 feet below Site GL–1. The tilting continued for 4,000 years after this before the artifacts were discovered.

Thus there seems to be a definite association of artifacts with the time of formation of an ancient beach that is almost 300 feet above present Lake Huron and two and one-half miles inland from it. The time of formation of this beach is exceedingly remote as compared with the time of occupancy of other archaeological sites about the Great Lakes. It was toward the close of the Pleistocene ice age, late in the Wisconsin glacial stage.

University of Michigan

POSTSCRIPT

The season of 1942 produced three new types of artifacts from the crest of the beach of GL–1: a hammerstone, a long, narrow leaf-shaped point, and a large punch or pick. One face of the last object is a single flake surface, and if the outline was intentional, it shows high skill in shaping the implement before its removal from the Levalloisian core by one blow. One fragment of a semilunar blade is waterworn. The other half, unworn, was found within ten feet of it in 1941. Where the broken ends fit the worn piece is one millimeter thinner than the unworn piece, which indicates the amount of quartzite that was removed by wave action. No movement had taken place among the flakes on the low ground between GL–1 and Lake Lumsden, though some were turned a little. An unusually dry winter may be the reason. The flakes were not removed. The area excavated at GL–1 was a workshop. Since the hammerstone lay in three pieces not more than three feet apart it suggests that all objects were rather close to their original positions. Three of the twenty artifacts found in 1942 and one large flake are waterworn. The lowest point at which artifacts occur at GL–2 was 890 feet above sea level.

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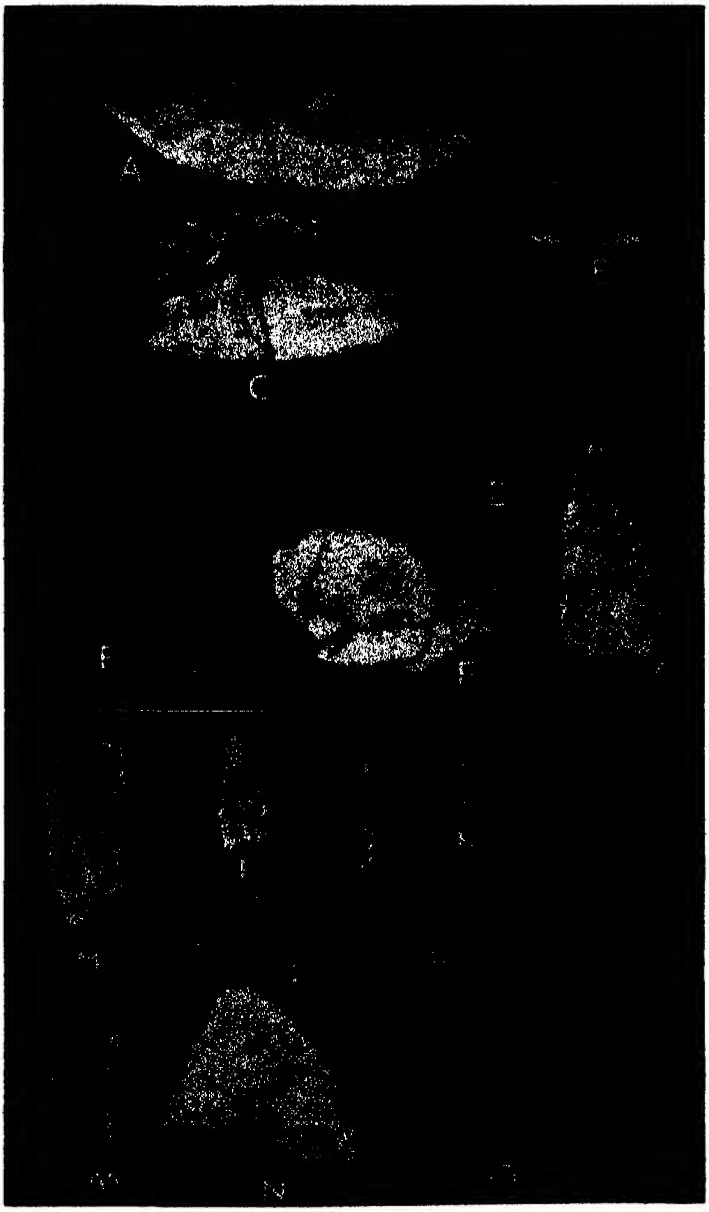

ARTIFACTS FROM THE GEORGE LAKE SITES

A, C, semilunar blades; B, half of a semilunar blade, rolled; D, quadrangular blade; E, chopper; F, tortoise bore; G, ovate blade; H, quadrangular blade with semilunar outline, smaller than the semilunar blades; I, J, K, perforators; L, M, N, utilized flakes; O, P, ovate blades. All artifacts are from G-L1, except L, which is from GL-2. Scale of A-G, $\frac{3}{10}$; scale of H-P, $\frac{1}{3}$

THE SOLAR DEITY OF THE TUNICA

MARY R. HAAS

IN AN article entitled "Sun Worship in the Southeast," published in 1928, Dr. John R. Swanton brings together a number of early references pertaining to the solar beliefs of various Southeastern tribes (9). Specific mention is made of the Natchez, Yuchi, Creek, Chickasaw, Choctaw, Chitimacha, Caddo, Cusabo, Timucua, and Cherokee. The Tunica, however, are not included in his list, probably because their solar myth was believed at that time to be lost (8, p. 318). In connection with field work on the Tunica language which was undertaken during the summer of 1933 and subsequently [1] I discovered that a fragmentary solar myth was still remembered by the last remaining speaker of the language, Sesostrie Youchigant.[2] This myth and other brief notes obtained from him throw new light on early references to Tunica religion and are also of interest when compared with the solar beliefs of other Southeastern tribes.

The essential points in the myth may be summarized as follows (3, Text No. 3): Once a very beautiful girl married Kingfisher. When she asked him for food he caught some minnows and brought them to her. This made her ashamed. She told him that he should remain on the water and eat minnows. She herself would go up into the sky to live. She sang and danced, and, as she was going up into the sky, she radiated light all about her. She became the Sun and now illuminates the whole world. It is for this reason that the Tunica Indians dance the sun dance.[3]

[1] This work was financed by the Committee on Research in American Indian Languages of the American Council of Learned Societies.

[2] This Indian and a few others of varying degrees of Tunica blood live near Marksville, in Avoyelles Parish, Louisiana. When first encountered by the white man, the Tunica were living near the mouth of the Yazoo River, not far from the present city of Vicksburg, Mississippi. Their migration from their original location to their present one was probably completed by the end of the eighteenth century. See Swanton, 8, pp. 307–318.

[3] There is little that can be said about this reference to the sun dance. Youchigant has never witnessed a performance of the dance and knows little about it except the song which was sung as its accompaniment. This song has been

There is an interesting point of resemblance between this myth and the solar myth of the Biloxi.[4] In the Tunica myth the Sun goes up into the sky because she is made ashamed by Kingfisher, whereas in the Biloxi myth it is because she is made ashamed by the Ancient of Otters.[5] In the Biloxi myth we are also told that since the Sun is ashamed people cannot see her well, i.e. cannot look directly at her. In the Tunica myth the significance of her shame is not made clear, but the interpretation, had it been recalled, might very well have been the same.

Perhaps the most important fact brought to light by the recovery of the Tunica myth is that their solar deity was female. In "Sun Worship in the Southeast" Swanton mentions only three tribes who considered this deity to be feminine, viz., the Yuchi, the Chitimacha, and the Cherokee (9, p. 211). To these the Tunica may be added as a fourth and the Biloxi as a fifth. Brief remarks found in the writings of two early observers indicate that the solar deity held a prominent position in Tunica religion. Father Gravier, who visited the tribe at the beginning of the eighteenth century, places the sun first in his list of Tunica gods, saying: "They acknowledge nine gods — the sun, thunder, fire, the gods of the east, south, north, west, of heaven, and of earth" (6, p. 133). La Harpe, writing not more than twenty years later, also makes an interesting statement regarding Tunica sun worship: "Leurs dieux pénates estoient un crapaud et une figure de femme qu'ils adoroient, croyant qu'ils représentoient le Soleil" (4, p. 247). The recovery of the Tunica solar myth makes it clear that the figure of a woman was intended to represent the solar deity herself, but the implied connection between her and the toad remains unexplained. This is probably due to the fragmentary nature of the myth as it has come down to us today.

Although Gravier's list of Tunica gods includes no mention of the moon, certain remarks made by Youchigant indicate that the moon may also have been a deity. He frequently spoke of the two luminaries together, pointing out that whereas the sun (*ta'hč'ʔi*) was

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phonographically recorded and will be published at a later time, together with other Tunica songs.

[4] The Biloxi myth is entitled "The Otter and the Sun"; Dorsey and Swanton, 1, pp. 107–111.

[5] In all other respects the two myths are quite different. Since the two tribes have been in close contact in recent times there is a possibility that this one point of resemblance is due to borrowing one way or the other.

a young woman, the moon (*ta'hč?a*) was an old woman or "granny." [6] Meager though this information is — for he recalls no explanatory myth — it is of particular interest in view of the fact that there is no other Southeastern tribe of which we have record in which both the sun and the moon are considered feminine beings. In an early account of Chitimacha beliefs the moon is represented as the husband of the sun (8, p. 357), whereas the Cherokee believed him to be her brother and lover (5, pp. 256–257). The Biloxi also represented the moon as a man, but in the fragmentary myth that is preserved no mention is made of a relationship between him and the Sun Woman (1, pp. 111–12). The evidence concerning Yuchi belief is conflicting. In one version of their creation myth, which depicts the sun as a woman, no mention is made of the moon; in another version of the same myth the sun is a man, the moon a woman (7, pp. 106–107; 12, pp. 147–150).

Another interesting point regarding Gravier's enumeration of Tunica gods relates to the fact that the sun and fire are listed separately. Among certain other Southeastern tribes it would appear that the sun and fire were regarded as but different manifestations of one and the same thing. The Natchez, for example, called the sun "the great fire," [7] and the Chickasaw formerly referred to their supreme being as "the great holy fire above" (10, p. 248). The Choctaw, according to Swanton, believed in "a supreme deity who, if not identical with the sun, was closely associated with and acted through that luminary and . . . was represented on earth by fire" (11, p. 196). Since our information concerning the Natchez, Chickasaw, and Choctaw beliefs suggests a direct association between the sun and fire, Gravier's separation of the two deities among the Tunica attracts attention. Although it would be a mistake to lean too heavily on the information which has been obtained from the modern Tunica, what there is of it seems to lend weight to Gravier's remarks. According to Youchigant, the Tunica believed that fire possessed the power of turning into any kind of being — man, woman, or animal. An instance of this sort is found in one of their tales wherein a campfire transforms itself into an old man in order

[6] Tunica is one of a very few North American Indian languages in which sex gender functions as a grammatical category (Haas, 2, p. 36). The words for sun and moon are proper nouns, and both are classified as feminine.

[7] Author's field notes on the Natchez language.

to give supernatural aid to an orphan boy in distress (3, Text No. 9). In commenting upon this episode the informant made a special point of the fact that, whereas the sun and thunder had originally been "real" people, fire had never been a person, even though he had the power of assuming human form.

This is all of our information with respect to Tunica beliefs concerning the sun, the moon, and fire. By way of summarizing the nature of these beliefs three points merit attention: (1) The Tunica solar deity was feminine and was probably the dominant figure in their religion; (2) Their beliefs regarding the sun and the moon contrast with those of other Southeastern tribes in that both luminaries were thought to be feminine beings; (3) There is no evidence to indicate that they associated fire with the sun in their worship, and it is possible that fire was considered a deity in its own right.

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THE POSITION OF POTAWATOMI IN CENTRAL ALGONKIAN

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THE first satisfactory comparative study of Algonkian was published by Bloomfield[1] in 1924. He gave particular attention to four languages, Cree, Ojibwa, Menomini, and Fox, and reconstructed, in formula fashion, the common ancestor of these four, calling it "Primitive Central Algonkian" (hereafter designated PCA in this paper). Since that time further study has brought about some minor changes in our picture of the parent language,[2] but to date no extensive effort has been made to correlate our information about any other Algonkian language with PCA. Whenever satisfactory descriptive material on any other Algonkian language becomes available, the problem immediately arises as to whether or not the new data will require major changes in our conception of the parent language; but except for an unsuccessful attempt to bring into view the Plains Algonkian languages (unsuccessful because our data on them are woefully inadequate)[3] and a good though still incomplete treatment of Delaware,[4] this type of problem has not previously been treated.

In the present paper the Potawatomi material gathered by the writer is brought under consideration.[5] It is first demonstrated that

[1] Bloomfield, Leonard, "On the Sound System of Central Algonkian," *Language*, 1 (1924): 130–156.

[2] Bloomfield, in "Algonquian Sketch" (unpublished manuscript, *c.* 1939), makes a number of revisions.

[3] Michelson, Truman, "Phonetic Shifts in the Algonquian Languages," *Internat. Journ. Am. Ling.*, 8 (1938): 131–171.

[4] Voegelin, C. F., "Proto-Algonquian Clusters in Delaware," *Language*, 17 (1941): 143–147.

[5] Field work on Potawatomi was done in the summers of 1937 and 1938 under grants from the Social Science Research Council and in the spring of 1940 under a grant from an anonymous donor through the University of Chicago. In the autumn of 1938, while working with the Oklahoma Kickapoo on a grant from the Institute of Human Relations of Yale University, the author spent a small amount of time in research on the local dialect of Potawatomi. During

no major changes in our conception of PCA are required for Potawatomi, and then the precise position of Potawatomi in the Algonkian family is discussed.

1. Potawatomi has five vowels: *i* (*machine*), *e* (*led*), *a* (*father*), *o* (*rôle*), and *ə*, (about like the *a* of *sofa*). Vowels are not found adjacent to each other, nor does a vowel begin a word.

There are six obstruent consonants: *p*, *t*, *č*, *k*, *s*, and *š*. These occur freely in all positions, and in clusters of two or more. Each single obstruent or obstruent cluster has two varieties: a lenis type, frequently voiced in voiced surroundings, and a fortis type (indicated by a postposed raised dot), which is longer, always voiceless, and more strongly enunciated. The fortis stops are not found in phrase-initial nor in phrase-final: *ʔo k·we*, 'the woman,' but *kwe*, 'woman,' in phrase-initial.

There are five nonobstruent consonants: *m*, *n*, *w*, *y*, and *ʔ*. These occur freely in all positions, and in clusters next to each other or next to obstruents.

2. At least in those dialects of PCA which underlay Potawatomi, southern Ojibwa, and Mohican [6] there seems to have been an accent, nonphonemic, which was distributed in words as follows:

(*a*) In dissyllables, with a single vowel in each syllable, the vowel of the second syllable bore the accent.

(*b*) In all other words the penult, if it contained a single vowel, bore the accent; apart from this, in any series of one or more syllables containing single vowels, the second, fourth, and each alternate one thereafter carried the accent.

(*c*) Every word ended in a single vowel, which carried the accent only under the conditions described in (*a*).

The remaining single-vowel syllables were unaccented.

In Potawatomi (hereafter designated P) all unstressed vowels are dropped; as is seen in the second and third examples below, a preceding semivowel drops also:

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the spring of 1939 the material that had been gathered at that time was organized into a monograph entitled "The Potawatomi Language," which was submitted to the faculty of the Graduate School of Yale University as a doctoral dissertation; work during that period was supported by the American Council of Learned Societies.

[6] Swadesh, Morris, "Mohican Lexical Material" (unpublished manuscript, 1939).

1. PCA **meçkwi*, 'blood'; P *msk·wə*.
2. PCA **elenyiwa*, 'man'; P *nənə*.
3. PCA **pemaatesiwa*, 'he lives'; P *pmatsə*.
4. PCA **nepemaatesi*, 'I live'; P *npəmatəs*.

3. Of the single vowels which remain in Potawatomi, PCA **i*, **e*, and **a* give ə; for **i* and **e* see the examples above; **a* is illustrated by:

5. PCA **nekamowa*, 'he sings'; P *nkəmo*.

The PCA double vowels **ii*, **ee*, and **aa* give P *i*, *e*, and *a* respectively, whereas both PCA **oo* and the cases of PCA **o* which are not lost give P *o*. For **aa* see *3*; for **o* see *5*. Examples of **ii*, **ee*, and **oo* follow:

6. PCA **miileewa*, 'he gives it to him'; cf. P *wminan*.
7. PCA **seekesiwa*, 'he is afraid'; P *seksə*.
8. PCA **manetoowa*, 'manitou'; P *mnəto*.

4. Potawatomi retains PCA postconsonantal **yee*, except that after *š* the *y* is lost; it is also lost after *č*, though in example *12* below the *y* is not followed by *ee*:

9. PCA **nyeewwi*, 'four'; P *nyew*.
10. PCA **myeewwi*, 'road'; P *myew*; cf. PCA **myeexkanaawi*, 'road, trail,' Ojibwa *miikkanaa*, Cree *meeskanaaw*.
11. PCA **meʔšyeewi*, 'it is large'; P *mš·e*.
12. PCA **neniičyaanehsa*, 'my child'; P *nničanəs·*.

Potawatomi data do not clarify the situation as regards post-consonantal and initial **we*. Initially the forms suggest PCA **we* rather than **o*, which some of the languages seem to require. Medially there are apparently instances of both.

13. PCA **wekimaawa*, 'chief'; P *wkəma*.
14. PCA **welaakani*, 'bowl'; P *wnakən*.
15. PCA **neto(o)kimaama*, 'my chief'; P *ntokmam*.
16. PCA **nekotwi*, 'one'; P *nkot*.
17. PCA **-kweʔθ-*, 'to fear'; in P *nkwəs·a*, 'I fear him.'

PCA interconsonantal **wi* drops the **w* in Potawatomi, and the **i* is treated like any other **i*:

18. PCA **keʔtwikaani*, 'farm'; P *kt·əkan*.
19. PCA **piintwikeewa*, 'he enters the lodge'; P *pitke*.

5. Single PCA consonants, initially or between vowels or semi-vowels, are retained in Potawatomi with only the changes below.

PCA **θ* and **l* (see *2* for **l*) give Potawatomi *n*:

20. PCA **neteθaawa*, 'I say so to him'; P *ntəna*.

PCA **h* and **ʔ* (if indeed they were distinct in PCA [7]) both give Potawatomi *ʔ*:

21. PCA *niimihetoowaki*, 'they dance together'; cf. P *nimʔətiwək*.
22. PCA **seekiheewa*, 'he frightens him'; cf. P *wsekʔan*.
23. PCA **neteeʔa*, 'my heart'; P *nteʔ*.

There are abundant examples of the other consonants in the forms already cited; *24* and *25* illustrate **š* and **y*:

24. PCA **iši*, 'thus'; P *šə*.
25. PCA **niiyawi*, 'my body'; P *niyəw*.

It is not known whether PCA had double vowels in word-initial or whether **ʔ* or **h* preceded. In Potawatomi *ʔ*– is found where some of the languages have smooth vowel-initial:

26. Fox *eemehkwaani;* P *ʔemk·wan*, 'spoon.'
27. PCA *(*ʔ*)*eehsepana* (**hs* not sure), 'raccoon'; P *ʔesp·ən*.

6. PCA clusters of **ʔ*, **h*, and **x* plus a consonant give Potawatomi fortis obstruents. If the second consonant of the cluster is **p*, **t*, **č*, **k*, **s*, or **š*, the result is Potawatomi *p·*, *t·*, *č·*, *k·*, *s·*, and *š·*, respectively; see *11*, *18*, and the examples below:

28. PCA **keʔči*, 'much'; P *kč·ə*.
29. PCA **aʔsenya*, 'stone'; P *s·ən*.
30. PCA **noohkomehsa*, 'my grandmother'; P *nok·məs·*.
31. PCA **nemehšoomehsa*, 'my grandfather'; P *nməš·oməs·*.
32. PCA **atooxpowa*, 'he eats on something'; cf. P *top·wən*, 'table.'
33. PCA **maxkesini*, 'moccasin'; P *mk·əsən*.

PCA **ʔl*, **hl*, **ʔθ*, and **hθ* probably all give Potawatomi *s·*, but I have no example of **hl*. See *17* and *34–36*:

34. PCA **aʔlapya*, 'net'; P *s·əp*.
35. PCA **neʔθeewa*, 'he kills him'; cf. P *wnəs·an*.
36. PCA **pemohθeewa*, 'he walks by, onward'; P *pmos·e*.

7. PCA **šp* and **šk* are retained, as is shown in *37–38*. There is no case of **št*.

37. PCA **išpemenki*, 'up'; P *špəmək*.
38. PCA **iškoteewi*, 'fire'; P *škote*.

PCA **çk* gives Potawatomi *sk·*, which is always fortis, from whatever source; see *1*.

PCA **čk* gives Potawatomi *k·*:

39. PCA **kečkyeewa*, 'he is old'; cf. P *kk·ya*.

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[7] Bloomfield now believes that of these two only a single phoneme existed in PCA, and that it appeared both independently and as the first element in clusters.

8. PCA clusters of a nasal plus a consonant drop the nasal in Potawatomi, and the following consonant develops as it does initially and intervocalically. Certain of the postulated PCA combinations have not been found, but see *19*, *37*, and the following examples:

40. PCA **noontaw*–, 'hear'; in P *wnotwan*, 'he hears him.'
41. PCA **waapantamwa*, 'he looks at it'; cf. P *waptan.*
42. PCA **wiintamaweewa*, 'he tells it to him'; cf. P *witməwan.*
43. PCA **tankeškaweewa*, 'he kicks him'; cf. P (conjunct) *tkəškwat.*

9. When a vowel drops and the adjacent consonants come into contact, certain changes take place. If, according to the shifts outlined above, either or both of the consonants would give a fortis obstruent, then the cluster as a whole is fortis in Potawatomi. Otherwise the cluster is lenis. To the examples already given (*7*, *18*, *19*, *27*, *28*, *39*, *41*, and *43*) may be added the following one:

44. PCA **netaxkehkooma*, 'my kettle'; P *ntəkk·om.*

When a semivowel comes to stand between two obstruents by the loss of a vowel, it is dropped; but in some dialects of Potawatomi *w* after *k* is an exception to this. Thus some speakers say *ktəmočke*, 'he is fishing,' but others say *kwtəmočke.*

The initial cluster **ww*–, arising through the loss of a vowel, is simplified to *ʔw*– or, optionally, to *w*–: *ʔwapman* or *wapman*, 'he sees him,' which contains the PCA prefix **we*– and stem **waap*–.

10. Probably more than 90 per cent of the morphemes of Potawatomi have cognates in Fox, Cree, Ojibwa, or Menomini corroborating the sound shifts just listed. There are some difficulties, of course, but no more than with the other four languages. It would therefore seem safe to conclude that Potawatomi is definitely a *Central* Algonkian language which requires very little modification of our conception of PCA.

On the other hand, it is not correct to say, with Michelson, that Potawatomi is simply a divergent Ojibwa dialect,[8] although it resembles Ojibwa in the following features:

(*a*) The loss of unaccented single vowels: this occurs in southern Ojibwa to a lesser extent.

(*b*) The merging of PCA **ʔ*–, **x*–, and **h*– clusters to give "long" consonants, though in Potawatomi the "longs" are phone-

[8] Michelson, "Preliminary Report on the Linguistic Classification of Algonquian Tribes," *Twenty-Eighth Ann. Rep. Bur. Am. Ethnol.*, 1906–7 : 221, 1912.

mically segmental phone plus accent, whereas in Ojibwa they are geminates.

(*c*) The development of **çk* into *sk* or *sk·*.

(*d*) The merging of **ʔ* and **h* into *ʔ* (when not the first element of a cluster).

(*e*) The endings of the independent mode of transitive verbs. Ojibwa and Potawatomi share a set which are not found elsewhere, and do not have the more generally distributed endings.

(*f*) The development of the dubitative mode.

(*g*) The development of a second obviative by superadding the obviative suffix to the form which already has it: *ʔok·məs·ən wtənnimnən*, 'his grandmother (obviative), her husband (second obviative)'; cf. *wtənnimən*, 'her husband' (first obviative).

Potawatomi is more like Fox and Shawnee, however, in the dropping, without trace, of the nasal of PCA nasal clusters, in the retention of interconsonantal **yee*, and in some other ways.

We may conclude that Potawatomi should be listed as a separate Algonkian language, of the Central type, rather than as an Ojibwa dialect, but that it is probably closer to Ojibwa than to any other language now spoken.

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THE CERAMIC SEQUENCE WITHIN THE GOODALL FOCUS

GEORGE I. QUIMBY, JR.

IT IS my purpose in this paper to construct a synthetic chronology as a temporal frame within which to view the ceramic content of a prehistoric Indian culture complex that I have elsewhere called the Goodall focus.[1] This focus consists of ten components or sites in northwestern Indiana and southwestern Michigan. All these sites were burial mounds or groups of burial mounds that contained various artifacts and other traits with a high degree of similarity. The Goodall focus belongs to one of the aspects of the Hopewellian phase,[2] which is distributed along the river valleys of the eastern United States from the Gulf of Mexico to Canada.

Archaeological evidence and studies of distribution indicate that the Hopewellian phase did not originate in northwestern Indiana or southwestern Michigan; therefore that part of this phase which is the Goodall focus must have entered its area of occupancy by some means of cultural diffusion.[3]

The ten components of the Goodall focus (Fig. 1) are distributed from south to north as follows: The Goodall site is within the drainage of the Kankakee headwaters in northwestern Indiana; the

[1] Quimby, George I., Jr., "The Goodall Focus, an Analysis of Ten Hopewellian Components in Michigan and Indiana," Indiana Historical Society, Prehistory Research Series, Vol. II (1941), No. 2.

[2] The terminology and the system of classification have been described by W. C. McKern, "Midwestern Taxonomic Method as an Aid to Archaeological Culture Study," *American Antiquity*, 4: 301–313. 1939.

[3] Cf. Eli Lilly, "Prehistoric Antiquities of Indiana" (Indianapolis, 1937), p. 28. J. A. Ford and Gordon Willey, *Crooks Site, Marksville Period Burial Mound in La Salle Parish, Louisiana*, Anthropological Study No. 3, p. 141 (Department of Conservation, Louisiana Geological Survey, New Orleans, 1940); James B. Griffin and Richard G. Morgan, "Contributions to the Archaeology of the Illinois River Valley," *Transactions of the American Philosophical Society*, N. S., Vol. 32 (1941), Part I, p. 47; Quimby, *op. cit.*, pp. 144–147; and James B. Griffin, "Additional Hopewell Material from Illinois," Indiana Historical Society, Prehistory Research Series, Vol. II (1941), No. 3, p. 213.

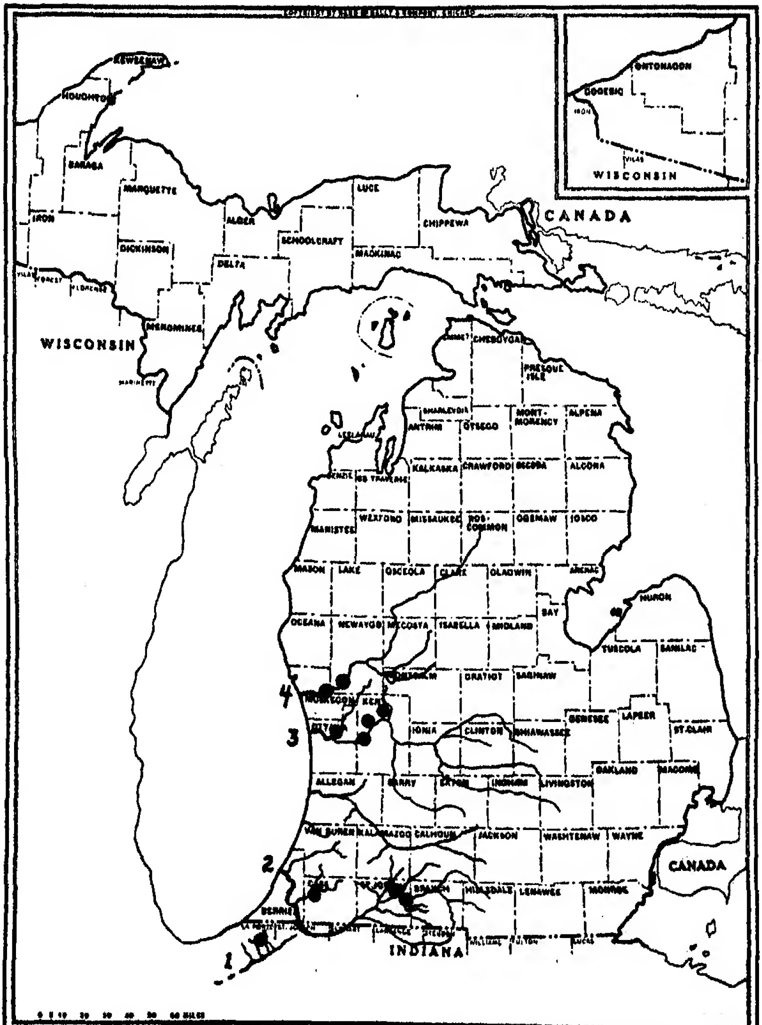

FIG. 1. Distribution of the Goodall focus mounds (indicated by solid circles) along the major drainage systems of southwestern Michigan and northwestern Indiana: (1) the Kankakee, which flows southwesterly into the Illinois River; (2) the St. Joseph; (3) the Grand River; (4) the Muskegon River. The south-to-north mound distribution is indicative of the movement of the Hopewellian culture into Michigan from Indiana and Illinois

Sumnerville, Scott, and Marantette sites are in the St. Joseph River drainage; the Gratten, Converse, Norton, and Spoonville sites are in the Grand River drainage; and the Brooks and McNeal sites are along the Muskegon River Valley. North of the Muskegon Valley there are few, if any, Hopewellian sites. Turning southward, however, we find the frequency of Hopewellian sites increasing. Although the Goodall site is the only one from the northern Kankakee drainage considered in this paper, there are, nonetheless, many others in that area.[4] Consequently, distribution, frequency, and cultural similarity indicate that the diffusion of the traits of the Goodall focus into northwestern Indiana and southwestern Michigan was essentially a south-to-north movement.

Translating the south-to-north spatial distribution into a temporal distribution, we see the sequence of culture change within the Goodall focus would be represented by sites ranging in date from those of the Kankakee drainage in the earliest period to those along the Muskegon in the latest period. The total span of time that can be assigned to this focus is probably not less than ten years and perhaps not much more. Such estimates, however, are based on no concrete evidence. If the assumed chronology is correct, then the occupancy of each drainage system would reflect a short period of culture. Named after their respective drainage systems, these would be, first, the Kankakee, then the St. Joseph period, next the Grand River period, and finally the Muskegon period. These four periods are the temporal frame within which one can analyze the ceramics of the Goodall focus.

In a previous paper I described and named the pottery types characteristic of the Goodall focus.[5] These types were based upon a classification of thirty-three vessels and a number of sherds. For the purpose at hand the sherds have been eliminated, because they were not always saved by the excavators of the various sites, whereas whole or restorable vessels were. To the total of vessels there has been

[4] McAllister, J. Gilbert, "The Archaeology of Porter County," *Indiana History Bulletin*, Vol. X (1932), No. 1. See also Lilly, *op. cit.*, pp. 86–92.

[5] Quimby, George I., Jr., "Hopewellian Pottery Types in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 26 (1940): 489–494. 1941. These pottery types are subject to revision. The trends described later in this paper will remain about the same even if the pottery types are changed. They also remain about the same when groups of individual pottery traits are used instead of pottery types.

added another of the Norton crosshatched type, from the Brooks site.[6]

The distribution of these vessels by periods and types is as follows:

KANKAKEE PERIOD: 1 Hopewellian zone-stamped; 4 Goodall dentate-stamped.

ST. JOSEPH PERIOD: 1 Hopewellian zone-stamped; 2 Goodall dentate-stamped; 5 Sumnerville incised; 1 generalized Woodland; and 1 unclassified, undecorated vessel.

GRAND RIVER PERIOD: 2 Hopewellian zone-stamped; 3, Sumnerville incised; 1 generalized Woodland; and 3 Norton crosshatched.

MUSKEGON PERIOD: 1 Hopewellian zone-stamped; 1 Sumnerville incised; 1 generalized Woodland; 5 Norton crosshatched; and 2 Brooks plain.

Pottery is generally considered the most sensitive indicator of culture change in space or time or both; therefore ceramic traits suggestive of culture change are probably much more obvious and easier to deal with than nonceramic traits. The graph, Figure 2, expresses by means of bar segments the percentages of the pottery types by periods. It possibly indicates some significant trends in ceramic sequence within the periods of the Goodall focus. Hopewellian zone-stamped is persistent throughout all four periods and probably represents an importation directly into the Goodall focus. The excellence of this ware as well as the limestone tempering prohibits the idea that it was manufactured locally. The most popular ceramic type of the Kankakee period was Goodall dentate-stamped. It is waning in the St. Joseph period and is not found in the later periods. The Sumnerville incised makes its appearance in the St. Joseph period and is declining in popularity during the Grand River and Muskegon periods. Norton crosshatched first appears in the Grand River period and is increasing in relative frequency in the Muskegon period. Brooks plain is a pottery type found only in the Muskegon period. Were there a period later than the Muskegon, there is a strong probability that Brooks plain would be present and increasing in popularity. The generalized Woodland pottery is found throughout all four periods, although I have listed it only for the St. Joseph, Grand River, and Muskegon periods. It does, however, occur at

[6] This vessel is in the Muskegon County Museum.

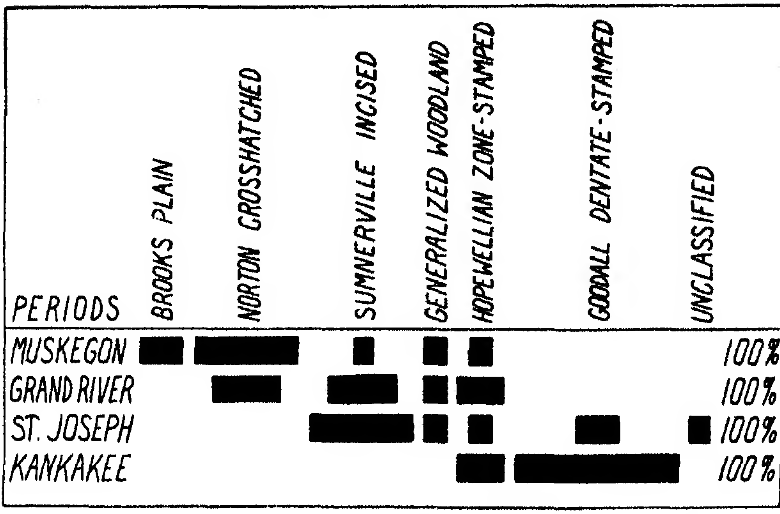

FIG. 2. Graph showing the relative increase or decrease or the stability of pottery types by periods. Each bar segment expresses the percentage of a given pottery type for a given period, and the total of the segments in each horizontal row is 100 per cent. The vertical arrangement of the segments illustrates the increase, decrease, or stability of each pottery type, from the oldest period (at the bottom) to the youngest one (at the top)

Hopewellian sites in the Kankakee drainage,[7] and its listing would not change the trends indicated by the graph.

The trends implied by the graph can have a number of explanations. The more or less uniform persistence of the Hopewellian zone-stamped has already been suggested as a direct importation. The generalized Woodland, which persisted, is most easily explained as a manifestation of the Woodland base that became Hopewellianized by diffusion. Goodall dentate-stamped seems to be an early introduced type that did not last throughout the life of the Goodall focus.

Sumnerville incised seems to have been largely the result of an imported idea, since it occurs in other Hopewellian foci. It is not, to my knowledge, found in the Kankakee period. This suggests that the Kankakee period had terminated by the time that Sumnerville incised concepts reached the St. Joseph Valley; otherwise the type

[7] Lilly, *op. cit.*, p. 90. With this exception the Goodall site is the only one considered in this paper.

should be found in sites within the northern Kankakee drainage. The type persisted throughout the remaining periods of the Goodall focus.

Norton crosshatched, for the most part, is probably an attempt by local potters to copy Hopewellian zone-stamped. Its greatest popularity is in the Muskegon period, which appears to terminate the life of the Goodall focus. Another Muskegon period type, Brooks plain, is also likely to have been a copy or a reaction to the stimulus of finer wares.

Incomplete Hopewellian manifestations are known to occur in the Saginaw Valley of eastern Michigan. Although no excavations have been made and no Hopewellian artifacts have been found associated with mounds, pottery sherds of the types Goodall dentate-stamped and Sumnerville incised, are represented in surface collections in which generalized Woodland sherds were predominant. If, then, the Hopewellian influences in the Saginaw Valley can be associated with the Goodall focus, they must have entered the Saginaw Valley during the Kankakee and St. Joseph periods.

Synthesis upon a broader scope may find these periods and ceramic trends of the Goodall focus to be at fault. The present analysis and interpretation have largely excluded data from other Hopewellian foci. Nevertheless, at the present time the ceramic sequence within the Goodall focus, as here described and interpreted, seems to have some foundation.

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NOTES ON HOPI WITCHCRAFT

MISCHA TITIEV

AMONG the Hopi, as is true of all the Pueblo Indians, a belief in witches (*poakam*) is so deeply ingrained that it colors a large part of their total culture. The prevalence of witchcraft is reputedly widespread, and there are said to be more sorcerers than normal people in each of the Hopi villages, even though ordinary persons may be unable to recognize them in everyday life. They may be of either sex and of any clan, and are to be found among all national, tribal, or racial groups, each unit of evildoers having its own chief.

The Hopi believe that all witches are the descendants of a mythological character known as the Spider Woman, who plays a prominent part in their stories of the beginning of human life on earth. According to these tales, all mankind originally lived in crowded quarters beneath the ground. The people fell into evil ways in the course of time, whereupon the chiefs decided to lead their good subjects up to the surface, leaving the malefactors underground; but during the emergence Spider Woman and several other *poakam* managed to come out with the others, and from them all present-day sorcerers are thought to have descended.[1]

From the Hopi point of view a witch is one who possesses extraordinary or supernatural power and who generally employs it for antisocial purposes. This ability to perform what may be called "black magic" is known as *duhisa*, and is supposedly derived from an animal familiar with which each *poaka* is intimately connected. The amount of *duhisa* varies with the nature of the associated beast, the greatest power being obtained from little black ants; but coyotes, wolves, owls, crows, bull snakes, cats, and dogs are also among the chief sources of evil strength. In keeping with this belief all witches

[1] Compare H. R. Voth, *The Traditions of the Hopi*, Anthropological Series, Field Columbian Museum, 8 (1905): 10, 11. Not long after Man had emerged on earth Spider Woman or one of her evil followers brought about the first death. Since then the Hopi have regarded witchcraft as the most common cause of death.

are commonly known as two-hearted, that is, possessed of an animal heart in addition to a human one.

Sorcerers maintain their numbers either by accepting voluntary recruits or by teaching their craft to little children who are unaware of what is being done to them. In such cases the witches are supposed to steal away sleeping youngsters after charming the parents into a deep slumber. A kidnaper of this type can take only a child who is related to him. The unconscious infant is hurried to a meeting ground called Palingwa, and there it is inducted into an evil order whose initiatory proceedings are modeled on those of the highly regarded secret societies which conduct Hopi ceremonies. Thus the novice must be introduced by a ceremonial father chosen from the ranks of the sorcerers, his head is washed in yucca suds, and he is given a new name. In addition, the candidate is taught how to transfer himself into the particular beast with which his sponsor is associated. If a ceremonial father has a coyote familiar, for example, he teaches his "godchild" to turn into a coyote. In the course of the initiation such metamorphoses are accomplished by somersaulting through a hoop,[2] and normal shape may be resumed by tumbling backward. The tyro is also taught to travel about by night and to take animal form promptly whenever he is in danger of being recognized. Having gone through the rites, the neophyte is considered to have acquired a second heart and the power to perform black magic. The whole procedure may take place, in the case of a kidnaped child, without his awareness of its meaning; and his parents, of course, have no inkling of the fact that their child has turned into a *poaka*.

Whether one has become involved wittingly or unwittingly, the duties of witches are the same, for all are dedicated to the taking of human life. To prolong his own existence, each sorcerer is obliged to cause the death of one of his relatives annually.[3] Thus *poakam* may be said to live by killing others, even if they pity them, just as ordinary people are forced to sustain their lives by butchering animals such as sheep or cattle. It is said that, if a repentant witch refuses to carry out his vow, he is doomed to die in the near future.

[2] For similar procedures among other Pueblo groups see Elsie Clews Parsons, "Witchcraft among the Pueblos: Indian or Spanish?" *Man*, 27 (1927): 106.

[3] It should be noted again that the Hopi firmly believe that witches can exert harm only on their relatives. Cf. Parsons, *loc. cit.*

As part of their antisocial behavior sorcerers also send caterpillars, grasshoppers, and other insects to destroy crops; may help speed the process of erosion which carries away much valuable farm land; and may drive off rainstorms in order to cause droughts and subsequent famine. There is a standard technique for the last-named practice. The two-hearted one takes four reeds, about half an inch in diameter and four inches long, and fills them lightly with a mixture of ashes (*qötcvu*) and a vaginal discharge (*hovalangwu*). The ashes represent dust, and the other substance is thought to be highly displeasing to the sky gods.[4] When rain appears imminent, the malefactor blows the contents of one of the reeds upward, whereupon the clouds promptly recede. This is done four times, after which the deities give up the attempt and take their rain elsewhere. One woman at Oraibi asserted that she had seen a witch driving off a rainstorm by a different method. He stood on a rock, peering at the heavens through little openings in the sides of his fists. Then he waved his arms away from the village, and a little later he motioned toward himself. These actions were interpreted as signifying that he had driven away the rain clouds and summoned a windstorm in their stead.[5]

Informants are agreed that the major activity of sorcerers is to cause illness and death among their relations by shooting foreign objects into them. Stiff deerhairs, red or black ants, centipedes, bits of bone or glass, and shreds of graveyard clothes are favorites. These are intruded into a person's body without his knowledge and without causing a scar at the point of entry.[6] Indeed, a patient seldom knows the cause of his sickness until a medicine man has "extracted" the harmful substance — likewise without leaving a scar. Once he has caused an ailment the *poaka* comes prowling nightly about the house in his animal shape,[7] sending renewed bursts of evil power through the roof or walls in order to keep his victim from getting well.

[4] The notion that the "smell" of women is displeasing to deities is so widespread that all participants in Hopi ceremonies must observe a tabu on sexual relations.

[5] The *poaka* in this episode was identified as a man named Nasiwaitiwa (see below), who had a village-wide reputation as a witch. The narrator maintained that the change of weather had actually occurred as a result of Nasiwaitiwa's actions.

[6] Compare E. C. Parsons, *Pueblo Indian Religion*, pp. 62–68.

[7] The frequent choice of dog or cat familiars, *dualangmosa*, was explained as a clever device for leading witnesses to mistake witches for harmless pets.

On the basis of a current belief that the same power which causes an ailment can also cure it the Hopi generally equate their shamans with witches. The difference in their behaviors is attributed to the fact that the former are two-hearted ones who have repented and are now trying to prolong their own lives by saving those of others. Don Talayesva, my principal informant, used to show great indignation whenever a medicine man was slow in coming to the aid of a patient. "They've got to be ready to help the people," Don would mutter angrily, "they've got to do it for their lives." Similarly, a story is told of one shaman who cured a sick boy by putting a grain of white corn on his chest and rubbing it into his body, thus giving him a new heart. Then the "doctor" said: "I am the one who has been killing you in order to keep up my own life, but I want you to live, so I'll cure you and die." He cured the patient, taught him his professional secrets, and died, but the boy lived on. Whenever a medicine man teaches his trade to a disciple, he is always said to "put another heart" into his pupil.

Not all shamans are looked upon with suspicion. Those who cure only by prescribing herbs and massaging or laying-on of hands need not necessarily be two-hearted, but those who set bones and who are capable of "extracting" witch-sent substances are usually classed as sorcerers. Two of the best-known practitioners on Third Mesa belonged to the latter category. The one less frequently consulted, Polingyauoma, a resident of Bakavi, became a curer when he was struck by lightning, and later dreamed that the cloud deities had thus imbued him with some of their power, which he had to use, on pain of death, for helping others. The more popular one, Kiacwaitiwa of Hotevilla, once made a vow in the course of a serious sickness that he would become a shaman if he survived. On his recovery, therefore, he had no choice but to cure others as long as he wished to remain alive.[8]

Because of the close connection between sorcery and curing all medicine men are regarded with a mixture of respect and fear. Indeed, many parents hesitate a long time before summoning a

[8] Informants would not, or could not, tell the details of how a shaman acquired the secrets of his profession. In former times the Hopi had a specific curing society which probably trained novices, but it has long been extinct. Some of its practices are described in *Hopi Journal of Alexander M. Stephen* (edited by Elsie Clews Parsons), pp. 857–863, *et passim* (Vol. 23 [1936] in *Columbia Contributions to Anthropology*).

native doctor because they are afraid to entrust their children to reputed sorcerers. Successful shamans, however, are well paid, and are very clever in taking advantage of Hopi beliefs by blaming their failures on the work of powerful witches over whom they have no control. A few practitioners are bold enough even to name openly the villagers whom they accuse of witchcraft, but most medicine men prefer not to betray suspected *poakam*, saying only, "Just keep your eyes and ears open, and you'll find out who is doing this."

Another reason why the Hopi suspect their shamans is based on their tendency to regard with distrust any person who shows exceptional power, or whose behavior is marked by individuality, eccentricity, recklessness, aggressiveness, daring, or bragging. This concept may be carried to extremes, as in the case of a woman who aroused suspicion merely because she broke her leg as a result of what looked like an easy fall. Similarly, even the highest officers in a pueblo may be accused of witchcraft, sometimes for no better reason than that they hold positions of such extraordinary importance. In other cases village chiefs may be accused of being two-hearted whenever anything goes wrong,[9] or whenever they behave in unconventional ways. Thus, for example, Chief Tawaqwaptiwa of Oraibi was denounced to me as a witch by one of his subjects because he had recently been earning his living by the manufacture and sale of *katcina* dolls, instead of by farming in the usual Hopi manner. Since this was a very uncommon practice, and meant that the chief no longer had any personal need for rain, it was argued that he had taken to using his great power for the evil purpose of driving off the clouds. In a comparable vein charges of witchcraft were leveled against Yokioma, leader of a rebellious faction that had seceded from Oraibi in 1906, simply because he had been sufficiently daring to challenge the authority of the traditional ruler and had been enterprising enough to rally a large following to his cause. Apparently, Yokioma was not averse to impressing the populace with his supposed magical power, for when his enemies accused him of having caused the great influenza epidemic of 1918 he boldly accepted the guilt.

Since insanity is the most obviously aberrant of all forms of conduct, it follows that all types of paranoia are regarded as having been caused by witchcraft. Two varieties of mental abnormality are

[9] Cf. Parsons, *op. cit.*, p. 106 (see note 2).

differentiated by the Hopi: one in which the subject is a two-heart who has made a voluntary pact to go insane and who "knows what he is doing"; and another in which the patient is the innocent victim of a sorcerer and goes violently mad. In either case demented people are held in the same fear as known *poakam*. Even the Oraibi chief did not dare to take measures against an insane villager named Ray Honkuku, and although Ray had frequently created disturbances and made things unpleasant for all the townsfolk, he was respectfully treated at all times and was even permitted to dine at the chief's house during his lucid intervals.

Since witches are most apt to injure those of their relatives whom they dislike, and since no one can tell which of his kindred may be a *poaka*, the Hopi live in perpetual dread of black magic.[10] A number of devices are employed for counteracting or preventing evil. Ashes, particularly from cedar wood, are frequently rubbed or smeared on persons or objects as prophylactics, and are widely used in rituals of exorcism.[11] Stone arrowpoints worn about the body are considered efficacious as amulets because they are looked upon as the ends of lightning bolts, and are thus endowed with some of the sacred power of the cloud gods.[12] Although they may be safely used in this manner, only medicine men and certain religious officers dare to handle them freely. Another trick used by the Hopi is based on the belief that sorcerers must limit their attacks to relatives. Accordingly, if a child is suffering from a witch-caused ailment, the parents may give it in adoption to an unrelated clan, thus providing it with a different set of kindred and making it safe from further harm at the hands of its assailant.[13]

Although they are willing to take some measures to protect themselves from witchcraft, the Hopi are very much averse to attacking particular sorcerers, even when they are supposedly caught in action. So great is the fear of a witch's revenge that it is considered foolhardy to attempt to kill one or to betray his identity.[14] Besides,

[10] There is a similar statement in Parsons, *op. cit.*, p. 107.

[11] See Parsons, *Pueblo Indian Religion*, pp. 462–464, *et passim*.

[12] Ancient stone implements are regarded with supernatural awe in many primitive societies.

[13] Adoptions of this type are purely symbolic, for the child neither changes residence nor repudiates its blood kindred. Actually, the new relatives are merely added to the old, yet this sort of adoption is supposed to throw a witch off the track.

[14] Once in a while a Hopi does try to kill a sorcerer, and Parsons, *op. cit.*,

once a sorcerer has been recognized, misfortune and death are supposed to follow automatically. To illustrate this principle, one young woman told me that a lock of hair had been mysteriously cut from her aunt's head, and that a short time later an old woman fell and broke her arm. "So you see," she concluded, "there are witches all around." In another instance a man whose daughter had been injured by graveyard sand which had been "shot" into the child's ear by a clanswoman explained that he was treating the sorceress kindly, but that he was watching her carefully, and already had the satisfaction of knowing that her husband had died soon after the child's illness had been diagnosed as due to witchcraft.

The worst thing that a person can do is to accept a bribe from a two-hearted malefactor, for the sorcerer is sure to repent his offer and to retaliate by harming the bribetaker. This aspect of the correct behavior toward evildoers is well illustrated by an episode that occurred when one of Don's sisters lay dying in childbirth. His father happened to step outside the house late at night and found an old woman looking right through the door "by magic." She was painted white, so that she could not be easily recognized. Don's father asked her who she was and what she was doing there at midnight, but she replied only that she had failed because she had been caught. Then, pointing to an object concealed under her dress, she said: "If you don't tell anyone I'll give you something." "Never mind," Don's father retorted, "I don't want it." "Well," said the witch, "I'll let you sleep with me." "I don't want any other woman while my wife is living," answered Don's father. He then followed the old woman, who had begun to hurry away, until he felt certain that he had identified her as Bakavi, one of the sick girl's grandmothers.[15] Nevertheless, despite the proper observance of Hopi rules for dealing with *poakam*, "This woman didn't die, and is now very old."

Because they are afraid to make any conscious effort to rid themselves of sorcerers it follows that many residents of the Hopi pueblos

pp. 108–109 (see note 9), gives a number of examples of authorized punishment among several Pueblo tribes, but on the whole they are far less ready than the Navaho to fire immediately at suspected witches.

[15] This incident was reported to Don Talayesva while he was ill at school in California, and served as one of the motivating factors in his trip to the home of the dead, which is described by M. Titiev, "A Hopi Visit to the Afterworld," *Pap. Mich. Acad. Sci., Arts, and Letters*, 26 (1940): 495–504. 1941. See especially pp. 496, 497, 502, 503.

continue to live under suspicion of being two-hearted. A few are branded as witches through identifications like the one described above; others get their labels from the diagnoses of medicine men, and some are put into this category by dying people who occasionally call out the names of individuals that are being revealed to them as witches. Those who find themselves suspected of sorcery frequently have to take advantage of the dread in which they are held in order to guarantee their own safety. For instance, Nasiwaitiwa, who was supposedly caught in the act of preventing rain (p. 551 and note 5), well knew that behind his back people often called him Poak Nasiwaitiwa (Nasiwaitiwa the witch). To put a stop to this practice he had only to say to his detractors: "I'm watching you all the time, and some day something is going to happen to you."

One of the most telling features of the Hopi attitude toward sorcerers is found in their religious notions. On the whole, Hopi religion is decidedly nonethical, but *poakam* are severely punished in the other world.[16] When ordinary mortals die their souls hasten to Maski, the home of the dead, where they lead existences comparable to life on earth. In contrast, the spirits of witches must make a slow and painful journey, suffering from thirst and hunger and traveling only one step a year. When at last they reach their destination they are stopped by guardians of the dead, who send them along a path culminating in a huge earth oven. Here they are thrown into a blazing fire, from which they emerge as beetles.[17] To avoid such an ending a witch sometimes crawls from its grave as a bull snake, and if someone kills it in this form its spirit is liberated and may travel at once to the Maski.

The constant terror of witchcraft under which the Hopi labor has had a marked effect on their characters. Brought up in an atmosphere of dread and helplessness in the face of evil attacks, they quickly learn to avoid all appearance of having exceptional ability, and to emphasize moderation in all things. They constantly decry their powers, make frequent professions of humility, and, through fear of arousing the envy or jealousy of the two-hearted, prefer not to seek great honors or to hold high offices. As Doctor

[16] Compare Parsons, *op. cit.*, p. 63 (see note 11). "To the Pueblo witchcraft and immorality or crime are almost synonymous." The only punishment inflicted in the other world on the one-hearted is the carrying of heavily laden baskets by those who have violated certain marriage regulations.

[17] For further details consult M. Titiev, *op. cit.*, pp. 497, 499–500.

Parsons has very aptly summed up the situation, "To keep clear of pernicious influences, whether from witch or Spirit, is fundamental in Pueblo motivation. It appears most plainly in ritual, but it controls other forms of conduct in social relations at large, whether of manners or morals. It enters into Pueblo ideas or feelings of discretion, prudence, and caution, producing a code of live and let live, of taking no responsibility apart from what is conventional, of suppressing or ignoring grief or distress. . . ."[18]

On countless occasions the Hopi may be heard exhorting one another to avoid grieving or worrying, for in this condition one is all the more susceptible to witch attacks. This attitude is most evident in the customs attendant on a bereavement. Only those relatives who are in the house when a death occurs are expected to weep, and even they are advised again and again to refrain. No family gatherings or funeral exercises are held, and burials are performed quickly and privately. The natives are far from indifferent to the loss of relatives or close friends, but they do not dare to get into a frame of mind that might make them easy victims of a *poaka*.[19]

Finally, Doctor Parsons has stated that she is inclined to "connect the very striking social timidities of the Pueblos with their witchcraft theories";[20] and Father Dumarest writes in the same vein. "Why," he asks, "are the Pueblo Indians so pacific? Why do they not try even to defend themselves in quarrels? Because from their youth their elders have taught them that nobody can know the hearts of men. There are witches everywhere. . . ."[21] It may be argued that Parsons and Dumarest are confusing cause with effect, for it is certainly possible that the personal timidity of these people has given rise to their witchcraft beliefs instead of their beliefs having caused their timidity; but however one chooses to interpret this phenomenon, no one can study the Hopi or any other Pueblo tribe without reaching the conclusion that the fear of witches plays a vital part in their patterns of culture.

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[18] Parsons, *op. cit.*, p. 107 (see note 11).

[19] The Reverend H. R. Voth, *Brief Miscellaneous Hopi Papers*, Anthropological Series, Field Columbian Museum, 11 (1912): 99–101, has called attention to the apparent indifference of the Hopi at the time of a death, but he made little effort to account for it.

[20] Parsons, *op. cit.*, p. 107 (see note 2).

[21] Dumarest, Noël, *Notes on Cochiti, New Mexico*, Memoirs of the American Anthropological Association, 6, No. 3 (1919): 162.

KERESAN INDIAN COLOR TERMS *

LESLIE A. WHITE

A FEW years ago I published brief lists of color terms from the Keresan Indian pueblos of San Felipe and Santo Domingo, New Mexico.[1] These data were obtained rather casually, merely to ascertain the Keresan names for a few common colors. They revealed, however, certain characteristics which indicated that further inquiry would be worth while.

In 1941 I went into the field with thirty-one color cards, carefully selected by a competent artist to represent the common, basic colors and shades. These cards were placed before native informants with the request that they supply the Keresan name for each color.[2] In this way data were secured from Santa Ana and Sia, both Keresan pueblos of New Mexico.

From my Santa Ana informant I obtained thirty-one distinct color descriptions. Two colors were given the same designation, but I received a color name for which I had no card, so that the total was thirty-one. My Sia informant named a number of colors individually and then grouped them into reds, blue-greens,[3] yellows, etc. We shall present the list secured at Santa Ana and use the data from Sia, Santo Domingo, and San Felipe for comparison and contrast. We shall list the colors, first, by their common names; secondly, by the names of the colors or shades in Robert Ridgway's *Color*

* Most of the data here presented were obtained on field trips supported wholly or in part by grants from the Horace H. Rackham School of Graduate Studies, University of Michigan, to which grateful acknowledgment is here made.

[1] White, Leslie A., *The Pueblo of San Felipe*, Memoir 38 (1932), Am. Anthropol. Assn., pp. 63–64, and *The Pueblo of Santo Domingo, New Mexico*, Memoir 43 (1935), Am. Anthropol. Assn., p. 201.

[2] No clew to the English names accompanied the color cards since informants frequently tend to *translate the words*, often inaccurately, rather than to *name the colors*.

[3] As will be seen in a moment, the Keres merge blues and greens into a single category, which they designate by a single term. We hyphenate "blue-green" to indicate, not a particular shade of green, but all shades of blue *and* green.

Standards and Color Nomenclature[4] which correspond most closely to our cards; and, thirdly, by their Keresan designations.

SANTA ANA COLOR TERMS

1. Medium blue (Rood's blue, Pl. IX), ɢuicgʋnyι.[5]
2. Dark blue (Prussian blue, Pl. IX), mʋ́na ('dark') ɢuicgʋnyι.
3. Light blue (squill blue, Pl. XX), cuwιmι ('turquoise') ɢuicgʋnyι.
4. Turquoise blue-green (Capri blue, Pl. XX), mockai (a local mineral used by the natives in the manufacture of paint; probably malachite, or copper sulphite) ɢuicgʋnyι.
5. Medium green (Killarney green, Pl. XVIII), kucáti.
6. Light green (deep malachite green, Pl. XXXII), kucáti ɢuicgʋnyι.
7. Dark green (Ackerman's green, Pl. XVIII), mʋ́na kucáti ɢuicgʋnyι.
8. Yellow green (yellow green, Pl. VI), káwinɑ ('lichen') ɢuicgʋnyι.
9. Red (scarlet red, Pl. I), k'ʋ́kanyι.
10. Dark red (carmine, Pl. I), mʋ́na ('dark') k'ʋ́kanyι.
11. Red orange (nopal red, Pl. I), ya·katc^{a} ('red ocher') k'ʋ́kanyι.
12. Orange red (between scarlet and scarlet red in Ridgway, Pl. I), ᴅyápi[6] (a shrub, mountain mahogany, *Cercocarpus argenteus* Rydb.) k'ʋ́kanyι.
13. Pink (geranium pink, or begonia rose, Pl. I), k'ʋ'ʋtckanyι.
14. Brown (liver brown, Pl. XIV). "It would be mi·ts [a clay] k'ʋ́kanyι if it were a little lighter," said the informant.
15. Light yellow (lemon yellow, Pl. IV), k'o·tcιnyι.
16. Medium yellow (apricot yellow, Pl. IV) h'á·ᴅawɛ ('pollen') k'o·tcιnyι.
17. Cream (pale orange yellow, Pl. III), gácɛ ('white') k'o·tcιnyι.

[4] Washington, D.C., 1912.

[5] We use here the simpler system of transcription as given in the article "Phonetic Transcription of Indian Languages," *Smith. Misc. Coll.*, 66, No. 6: 2–5. Washington, 1916.

a	as in *father*	ɑ	as in *but*
e	as in *fate*	ɛ	as in *met*
i	as in *pique*	ι	as in *pin*
o	as in *note*	ʋ	as in *put*
u	as in *rule*	c = sh	

ʙ is intermediate b–p; ᴅ, intermediate d–t; ɢ, intermediate g–k.

[6] Informants almost always comment upon the fondness of deer for the leaves of ᴅyápi. A reddish dye for coloring moccasins and leggings is made from this shrub.

18. Ivory (massicot yellow, Pl. XVI), ipctc (a whitish clay used as a body paint and also for the slip of pottery vessels) k'o·tcɪnyɪ.
19. Yellow orange (mikado orange, Pl. III), k'ʊ́kanyɪ ('red') k'o·tcɪnyɪ.
20. Brown (Natal brown, Pl. XL), kwi′stɪrɪ.
21. Tan (cinnamon, Pl. XXIX), ckaiyo· ('gray') kwi′stɪrɪ.
22. Terra cotta (orange-rufous, Pl. II), k'ʊ́kanyɪ ('red') kwi′stɪrɪ.
23. Medium orange (grenadine red, Pl. II), "almost k'ʊ́kanyɪ kwi′stɪrɪ."
24. Deep yellow (ochraceous orange, Pl. XV), gáce ('white') kwi′stɪrɪ.
25. Light gray (pale mouse gray, Pl. LI), ckaiyó·tsa.
26. Medium gray (neutral gray, Pl. LIII), ipctc ('whitish clay') ckaiyó·tsa.
27. Dark gray (dark mouse gray, Pl. LI), mʊ́na ('dark') ckaiyó·tsa.
28. Red brown (Vandyke red, Pl. XIII), ʙici·na.
29. Red violet (true purple, Pl. XI), gáce ('white') ʙici·na.
30. White, gáce.
31. Black, mʊ́nak'anyɪ.
32. Color of dark-blue corn, k'á·mʊna.

A characteristic feature of Keresan color nomenclature, as shown by the data from Santa Ana, Sia, San Felipe, and Santo Domingo, is the merging of blues and greens; shades from dark blue to yellow green are called *guicgunyi*,[7] modified, of course, by various terms meaning "lichen," "turquoise," etc. Our Sia informant did not always agree with the one from Santa Ana in the selection of the color or the shade which corresponds to the basic color terms. Thus the latter selected medium blue, No. 1 in our list, as the color most appropriately called *guicgunyi;* the Sia informant selected No. 5, medium green. For *kukanyi* ("red") the Santa Ana selected No. 9, scarlet red; the Sia chose No. 12, orange red. For *kotcinyi* (yellow) the Santa Ana chose No. 15, light, or lemon, yellow; the other picked No. 16, medium, or apricot, yellow. They were in agreement, however, in selecting No. 20, Natal brown, for *kwistiri;* No. 25, light gray, for *ckaiyotsa;* and No. 28, Vandyke red, as *bicina.*

Our Santa Ana informant had difficulty in deciding what to call certain shades, particularly No. 19, yellow orange, which he called

[7] From this point on we shall spell Indian words phonetically only on their first occurrence.

"reddish yellow"; No. 22, terra cotta, which he called "reddish brown"; and No. 23, medium orange, which he also called "reddish brown." The Sia informant put these three shades in the class red (*kukanyi*). The Santa Ana probably would not have objected to this since he called each one "reddish."

There are a few other slight differences between these two. The Sia placed No. 24, deep yellow, in the yellow class, whereas the Santa Ana called it "whitish brown." The latter called No. 29, true purple, "whitish Vandyke red"; the former simply classed it with "red."

As is well known, some words in the color nomenclature of the English language, such as "red," "yellow," "green," and "blue," refer primarily to colors. Other terms are derived from words which originally did not designate colors at all. Thus "orange" and "lemon" are taken from the names of fruits; "vermilion" comes from *vermis*, "worm"; "maroon" from *marron*, a French chestnut; "purple" from *porphyra*, the purple fish; "magenta" is the name of a town in Italy. Then, of course, there are such terms as "claret," "rust," "flaxen," "copper," and "brick."

In Keresan color nomenclature we may well have the same situation. There are, without doubt, words which designate colors and colors only. There may be — and we suspect there are — terms which are primarily names of objects and which, because of the characteristic colors of the objects, come to stand for certain colors. At the present stage of our investigations it is impossible to say definitely which are which. We feel sure that *kukanyi* ("red"), *kotcinyi* ("yellow"), *guicgunyi* ("blue-green"), *kwistiri* ("brown"), *munakanyi* ("black"), and *gace* ("white") are primarily and essentially color terms. These words are used as color names in each of the four Keresan pueblos under discussion. *Ckaiyotsa* ("gray") appears also to be primarily a color term, although at San Felipe we find mo·na-é-gace ("black and white") for "gray." K'ʋ'ʋtckanyɩ ("pink") looks like a form of *kukanyi* ("red"). Our Sia informant called pink koctye·ina, which is the only occurrence of the word we have noted. He also called pink k'ʋ'ʋtckanyɩ. *Kamuna*, "the color of dark-blue corn," seems to be cognate to *monakanyi* ("black" or "dark"). At San Felipe we find k'amoná·tsa, which also appears to be a cognate form of *monakanyi*, applied to the deep blue of the sky.

The term *kucati* is puzzling. At Santa Ana all greens and blues were called *guicgunyi* save one, Killarney green, which was called *kucati.* Two other greens were called *kucati guicgunyi* and *muna (dark) kucati guicgunyi.* Our Sia informant, when asked about the term, also selected Killarney green, calling it, however, kucaDi'-matsɛ. He had previously chosen Killarney green as typically *guicgunyi*. In discussing the word *kucati* our Santa Ana Indian said that "yeast is called *kucati.*" The Pueblo Indians did not know yeast before the advent of the whites. He added: "When you say *kucati* fast, it means 'rotten.'" We did not find this word at Santo Domingo or San Felipe. We suspect that *kucati* is not primarily a color term; it may possibly be analogous to our "rust" or "claret."

In our work with the Keres we have frequently met the color term *bicina*, but, with one exception, only in reference to corn of a purplish color. At Santo Domingo, on one occasion, "deep blue" was called Bi'cinatsa. We suspect that *bicina* is not primarily a color term, but is analogous to "flaxen" or "brick."

It is interesting to note, especially at Santa Ana, a practice similar to ours, that of qualifying color terms with the names of things having a characteristic shade. Thus, as we say "apple green," "cherry red," and "lemon yellow," the Keres say "lichen green," "clay gray," "pollen yellow," and "mountain mahogany red."

This study, far from being exhaustive, contains, nevertheless, about all that we know about Keresan color terms at the present time.

UNIVERSITY OF MICHIGAN

FOLKLORE

PRAISE AND DISPRAISE IN FOLKLORE *

EUGENE S. McCARTNEY

WE ARE told by Plutarch (*Mor.* 59A) that a field remains unaffected by commendation, whereas a man who is praised beyond his deserts is puffed up and destroyed.[1] Today, also, praise may turn a person's head,[2] but in the realm of superstition its consequences are literal rather than figurative, and it is devastating physically as well as spiritually. It is often resorted to by people who have the evil eye. Its harmful potentialities may, in fact, be summed up in the same striking words with which an American scholar described those of this malign power:

> The Evil Eye may be the cause of every ill in mind, body or estate that flesh is heir to; briefly, of misfortunes which in modern times are covered by insurance, attributed to the weather or for which the remedy is sought by recourse to a lawyer, a physician or a gun, according to the temperament of the loser. Above all, the Evil Eye is responsible for those slow, wasting diseases and nervous or mental disorders for which the untutored mind can find no explanation in the circumstances of the person afflicted. Anyone may be blighted by it, babies in the cradle especially.[3]

* The following works will be referred to by the authors' names only: G. F. Abbott, *Macedonian Folklore* (Cambridge, 1903); F. T. Elworthy, *The Evil Eye: An Account of This Ancient and Widespread Superstition* (London, 1895); W. Gregor, *Notes on the Folk-Lore of the North-East of Scotland* (London, 1881); R. C. Maclagan, *Evil Eye in the Western Highlands* (London, 1902); B. Schmidt, "Der böse Blick und ähnlicher Zauber im neugriechischen Volksglauben," *Neue Jahrb. f. klass. Altertum*, 31 (1913) : 574–618; S. Seligmann, *Der böse Blick und Verwandtes* (Berlin, 1910); W. W. Story, *Castle St. Angelo and the Evil Eye* (London, 1877).

1 Cf. Luke iv. 26: "Woe unto you when all men shall speak well of you."

2 Cf. Emerson, *Compensation:* "Blame is safer than praise. I hate to be defended in a newspaper. As long as all that is said is said against me, I feel a certain assurance of success. But as soon as honeyed words of praise are spoken for me I feel as one that lies unprotected before his enemies."

3 K. F. Smith, "Pupula Duplex," *Studies in Honor of Basil L. Gildersleeve* (Baltimore, 1902), p. 293. The great work on the evil eye is, of course, that of Seligmann (as cited in the introductory note). It supersedes a remarkable contribution to the subject by Otto Jahn, "Über den Aberglauben des bösen Blicks bei den Alten," *Berichte der königlich sächsischen Gesellschaft der Wissenschaften zu Leipzig*, Phil.-hist. Classe, 7 (1855) : 28–110. See also B. Schmidt; F. T. Elworthy;

The blasting effects of praise are not confined to human beings, for it destroys cattle, vegetation, and even objects without life. In the main the dangers have come from three sources: (1) the inadvertence or the ignorance of well-meaning people who let slip complimentary remarks; (2) the envy and malevolence of those who have the evil eye; and (3) the jealousy of the gods,[4] who permit no mortal to be supremely beautiful or happy or prosperous without paying for his blessings by counterbalancing woes and adversities. In modern times even fairies have been resentful of the bestowal of praise, especially in Ireland. Expressions of admiration and the display of love and affection have likewise brought heavy calamities. These and related aspects of praising I desire to illustrate by examples from both ancient and modern Greece and Italy, from several other countries bordering on the Mediterranean Sea, and from a few places remote from the classical lands.

It happens that numerous ancient beliefs about praise and the evil eye that are recorded in colorless statements of fact by Greeks and Romans are strikingly paralleled by modern ones in story settings. In the Mediterranean countries material of this kind illuminates the superstitious past more clearly and accurately than a novelist can re-create the atmosphere of a bygone era. Especially close analogues to classical notions may be found in books dealing with the lore of Gaelic-speaking parts of Scotland. Many examples have been collected by R. C. Maclagan, *Evil Eye in the Western Highlands*,[5] a volume which cannot fail to give the reader a better understanding of classical ideas about the dangers of praising.

A meager generalization about praise occurs in Pliny the Elder (*Nat. Hist.* 7.16). He says that certain families in Africa who were gifted with powers of fascination employed praise as a means of killing cattle, blighting trees, and causing the death of children: ". . . quorum laudatione intereant probata, arescant arbores, emori-

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W. B. McDaniel, "The Pupula Duplex and Other Tokens of an 'Evil Eye' in the Light of Ophthalmology," *Class Phil.*, 13 (1918): 335–346. Material of special interest for my subject will be found in the *Handwörterbuch des deutschen Aberglaubens* (Berlin and Leipzig, 1927—), under the articles "Auge," I: 685–690; "berufen, beschreien," I: 1096–1102; and "loben," V: 1311–1316. An article on "unberufen" is announced for a supplement to the *Handwörterbuch*.

[4] See, for instance, H. V. Canter, "Ill Will of the Gods in Greek and Latin Poetry," *Class. Phil.*, 32 (1937): 131–143; Karl Nawratil, *θεῖον ταραχῶδες*, *Philologische Wochenschrift*, 60 (1940): 125–126.

[5] For bibliographical data see the introductory note.

antur infantes." A Roman's understanding of Pliny's brief statement may be found in Aulus Gellius (*Noct. Att.* 9.4.7–8): ". . . esse quasdam in terra Africa hominum familias voce atque lingua effascinantium qui si impensius forte laudaverint pulchras arbores, segetes laetiores, infantes amoeniores, egregios equos, pecudes pastu atque cultu opimas, emoriantur repente haec omnia, nulli aliae causae obnoxia."

This circumstantial account of Aulus Gellius is far more interesting than the few matter-of-fact words of Pliny, but it may be somewhat misleading. As we shall see, in general folk practice it is by no means essential that the praise be lavish or casual or unguarded, ("si impensius forte laudaverint"), nor do the persons or things singled out for attention have to be in a particularly flourishing condition. Like the jealous gods, the evil eye may prefer to strike down the exalted and the prosperous,[6] but it may blast any person or any thing attractive enough to call forth a compliment, whether spontaneous and sincere or premeditated and malicious. "And the same bad effect can be produced by the look or glance of the eye of the man who, while uttering words of praise or congratulation, makes a mental reservation whereby he produces the exactly opposite effect of that which his words seem to wish to make."[7]

One may well ask how the evil effects of praise were communicated from one person to another. Some of the ancients thought that feelings of envy aroused on seeing something excellent filled the atmosphere with a pernicious quality and that an envious man transmitted his own envenomed exhalations to the things nearest to him.[8] The eye was the window of the mind or soul,[9] and for this reason,

[6] Cf. Abbott, p. 140: "The curse [of the evil eye] is to be dreaded most when its object is in an exceptionally flourishing condition: a very healthy and good-looking child, a spirited horse, a blooming garden, or a new house, are all subject to its influence."

[7] Sir E. A. Wallis Budge, *Amulets and Superstitions* (London, 1930), pp. 354–355.

[8] Heliodorus, *Aethiop.* 3.7; Plut., *Mor.* 681 F.

[9] Lactantius says that the thoughts and wishes are often seen in the eyes (*De Opificio Dei*, 8.12) and that they are, so to speak, the windows of the mind (*ibid.* 9.2). Quintilian (*Inst. Orat.* 11.3.75), who studied the matter from the standpoint of the orator, declares that the mind or soul is revealed through the eyes. Pliny (*Nat. Hist.* 11.145) assures us that no part of the body gives a clearer index of the mind, and he concludes that the mind has its seat in the eyes ("Profecto in oculis animus habitat"). Cicero (*De Orat.* 3.221) states that the eye is the only part of the body that registers all changes of the mind.

probably, a glance from the envious was supposed to corrupt and contaminate the air.

There are many aspects of the subject of praising, and one story or one quotation may illustrate three or four of them. For this reason my arrangement of material is sometimes arbitrary. Furthermore, pertinent cross references are omitted, since their introduction would encumber the article and make it unduly long.

PRAISE OF INFANTS

We know that infants, children, and those in the bloom of youth were especially susceptible to the evil eye,[10] for many precautions were taken to guard them against exposure to it. Some Greek mothers went so far as to refuse to show children to their fathers (Plut., *Mor.* 682 A), and an old Roman granny or aunt would lift a baby from the cradle and apply spittle to the forehead in an effort to protect it from danger (Persius, 2.31–34). A Roman nurse tending a baby spat three times in its face if a stranger entered the house or if someone saw the child while it was sleeping (Pliny, *Nat. Hist.* 28.39). The peril was so imminent that the Romans created a special goddess of the cradle, Cunina (Lactant., *Div. Inst.* 1.20.36). Ancient lore would tend to confirm, therefore, Pliny's record of the deadliness of praise bestowed upon infants. At the present time an unguarded compliment or an admiring glance may be equally disastrous. A modern Greek admonition that stresses the welfare of the newborn babe runs as follows: "Do not be too eager to compliment a mother on the birth of an infant, but remain at least half an hour in the house before entering her room, lest rejoicing turn to lamentation." [11]

We find that the Osmanli women of Turkey are best pleased when the new arrival is totally ignored and so is spared the risk of having the evil eye cast upon it. "If, however, feminine curiosity and interest in babies are too strong to allow of the infant's being

[10] Alexander of Aphrodisias asks (2.53) why certain people fascinate young children especially. Cf. Plut., *Mor.* 680 D. Pliny, *Nat. Hist.* 7.16, notes that *puberes* were particularly susceptible to the evil eye. The gypsies of Spain believe that because of "the tenderness of their constitution" children were more easily blighted than older people. See George Borrow, *The Zincali: An Account of the Gypsies of Spain* (London, 1907), p. 115. Cf. Verg., *Ecl.* 3.103: "Nescio quis teneros oculus mihi fascinat agnos."

[11] *Folk-Lore Journal*, 1 (1883): 220. Cf. Abbott, pp. 141–142.

entirely overlooked, the *hanüms*, after spitting on it, conceal their admiration under some such disparaging remarks as 'Nasty, ugly little thing!' to show that they bear no malice." [12]

Part of an account of the Turkish ceremony after the birth of a child is worth quoting here:

> . . . Very little notice is taken of the baby, and even then only disparaging remarks are made about it, both by relatives and guests, such as *Murdar* (dirty), *Chirkin* (ugly), *Yaramaz* (naughty). If looked at it is immediately spat upon, and then left to slumber in innocent unconsciousness of the undeserved abuse it has received. Abusive and false epithets are employed by Turkish women under all circumstances worthy of inviting praise or admiration, in order to counteract the supposition of ill-feeling or malice underlying the honeyed words of the speaker, which are sure to be turned against her in case of any accident or evil happening to the subject of the conversation.[13]

The danger caused through praising a child in the cradle may be illustrated by a story related by a Moor of Tripoli early in the nineteenth century:

> . . . A person possessed of the evil eye, being once on a journey, chanced to enter a cottage where he saw an old woman, and a child which lay sleeping in a cradle; he requested that some milk might be given him to quench his thirst, but there was unfortunately none in the house; having remained some time to repose himself, he was observed to gaze steadfastly on the infant, and [having] admired its beauty, he soon after departed; on the mother's awaking next morning, she found her child dead! occasioned of course by the evil eye of the preceding day.[14]

A half century ago superstitious mothers in the northeastern part of Scotland took measures to shield their babes from the dangers of praise. "To guard the child from being *forespoken*, it was passed three times through the petticoat or chemise the mother wore at the time of the accouchement. It was not deemed proper to bestow a very great deal of praise on a child; and one doing so would have been interrupted by some such words as 'Gueede sake, haud yir tong, or ye'll forespyke the bairn.'" [15]

The Slavs have a similar superstition, and a Russian nurse has

[12] Lucy M. J. Garnett, *The Women of Turkey and Their Folk-Lore: The Jewish and Moslem Women* (London, 1891), p. 475.

[13] *The People of Turkey: Twenty Years' Residence among Bulgarians, Greeks, Albanians, Turks, and Armenians*, by a Consul's Daughter and Wife [Mrs. John Elijah Blunt], edited by Stanley Lane Poole (London, 1878), p. 5.

[14] E. Blaquière, *Letters from the Mediterranean, containing a Civil and Political Account of Sicily, Tripoly, Tunis and Malta* (London, 1813), II: 70–71.

[15] Gregor, pp. 7–8.

been known to spit in the face of one who praised her ward without uttering the precautionary "God forbid." [16] In Germany, likewise, parents and nurses have had misgivings when their children were praised.[17]

Young children are protected from the effects of the evil eye with as much solicitude as babes. The English traveler Edward Dodwell relates an interesting experience on the island of Corfu in the first decade of the nineteenth century. His account runs as follows:

> . . . I was taking a view near a cottage, into which I was kindly invited, and hospitably entertained with fruit and wine. Two remarkably fine children, the sons of my host, were playing about the cottage; and as I wished to pay a compliment to the parents, I was lavish in my praises of their children. But when I had repeated my admiration two or three times, an old woman, whom I suppose to have been the grandmother, became agonized with alarm, and starting up, she dragged the children towards me, and desired me to spit in their faces. This singular request excited so much astonishment, that I concluded the venerable dame to be disordered in her intellects. But her importunities were immediately seconded, and earnestly enforced, by those of the father and mother of the boys. I was fortunately accompanied by a Greek, who explained to me, that in order to destroy the evil effects of my superlative encomiums, the only remedy was, for me to spit in the faces of the children. I could no longer refuse a compliance with their demands, and I accordingly performed the unpleasant office in as moderate a manner as possible. But this did not satisfy the superstitious cottagers; and it was curious to see with what perfect tranquillity the children underwent the nasty operation; to which their beauty had probably frequently exposed them. The mother then took some dust from the ground, and mixing it with some oil, from a lamp which was burning before a picture of the Virgin, put a small patch of it on their foreheads. We then parted perfectly good friends; but they begged of me never to praise their children again.[18]

Over fifty years ago the household of a Greek lady in Smyrna showed in the presence of a guest how dangerous it is for a child to be praised even by members of the immediate family.

> . . . Her little grandson, who had just arrived from Europe, was, during luncheon, an object of great interest to his grandmother and aunts, who overwhelmed him with laudations. To every complimentary remark, however, made to, or about him, by either this lady or her daughters, another would exclaim, "No! garlic! garlic!" (Όχι! σκόρδον! σκόρδον!), at the same time

[16] Jacob Grimm, *Deutsche Mythologie*, besorgt von E. H. Meyer (Berlin, 1872), II: 923.

[17] John Aubrey, *Remains of Gentilisme and Judaisme, 1686–87*, edited and annotated by James Britten (London, 1881), p. 80. Cf. *Handwörterbuch des deutschen Aberglaubens*, s.vv. "berufen, beschreien," I: 1098.

[18] Edward Dodwell, *A Classical and Topographical Tour through Greece during the Years 1801, 1805, and 1806* (London, 1819), II: 35–36.

pointing at the child, thus threatened with the evil eye, the first and second outstretched fingers. For the evil eye may also be cast unwittingly, . . . and it is impossible in the Levant to speak admiringly or approvingly of any person or thing without being met with the exclamation, "*Kalé!* don't give it the evil eye!" (*καλή. μὴ τὸν ματιάζῃς!*)[19]

Tourists who are unaware of the existence of this superstition about praising may inadvertently incur some risk of bodily harm, as we learn from the words of a classical scholar: "I have seen in modern Greece, within twenty miles of Delphi, a party of American and Canadian women in danger of being stoned because in the little village of Arachoba, inhabited by Albanians, they had artlessly praised the beauty of the local children."[20]

A Greek physician who traveled about the Aegean Sea early in the nineteenth century found the belief widely current among the peoples of the Levant:

. . . ils tombent d'accord entre eux que lorsqu'on parlera de la bonté ou de la beauté de quelque objet, soit animé, soit inanimé, ils ajouteront, en une langue quelconque, *Dieu le préserve;* c'est ainsi que les Grecs disent en soufflant de la salive sur l'objet qu'ils flattent, *na min ambascathi*, ou *mati na min to piassi.* Les Turcs, qui se soumettent strictement à cette pratique, ne manquent jamais de dire, en pareil cas, le mot *machalach!* (ce que Dieu a fait). Cette influence, selon eux, se faisant sentir particulièrement aux enfants, on a recours pour les garantir à l'ail et à la couleur bleue. Les personnes riches font monter en argent une pierre bleue de quelque nature qu'elle soit, et une racine d'ail, qu'on suspend au bonnet que l'enfant porte habituellement.[21]

Examples of similar beliefs may be adduced from other lands bordering on the Mediterranean Sea.

The people of Palestine do not like to hear themselves complimented unless at the same time you use the name of God. Otherwise they believe such expressions are bound to bring misfortunes and possibly troubles and death. If you call a boy or a girl pretty its mother's heart is filled with terror, and she straightway throws out her hand, extending the index and little finger in a way supposed to ward off the devil and to prevent the evil consequences of your remark. If you wish to praise the beauty of a child you must begin the sentence with, "May God surround thee." After that you may go on as you please. If you pat the child on the head and fail to use this sentence, the mother upon returning home will take the child into a room and put it in the middle of the

[19] Lucy M. J. Garnett, *The Women of Turkey and Their Folk-Lore: The Christian Women* (London, 1890), p. 146. See also Mrs. Murray-Aynsley, *Symbolism of the East and West* (London, 1900), p. 144.

[20] M. Hutton, *The Greek Point of View* (New York, 1925), p. 162. Cf. Abbott, p. 141.

[21] M. Zallones, *Voyage à Tine, l'une des îles de l'Archipel de la Grèce* (Paris, 1809), pp. 156–157.

floor. She will then take a shovel and gather dust from each of the four corners, and throw it into the fire, crying: "Fie on thee, evil eye." [22]

A passage published in 1743 concerning the evil eye among the Egyptians is informative:

They have a great notion of the magic art, have books about it, and think there is much virtue in talismans and charms; but particularly are strongly possessed with an opinion of the evil eye. And when a child is commended, except you give it some blessing, if they are not very well assured of your good will, they use charms against the evil eye; and particularly when they think any ill success attends them on account of an evil eye, they throw salt into the fire.[23]

In the second decade of the last century an English traveler found in northern Africa an Arab belief part of which reminds one of the passage quoted from Aulus Gellius (p. 569), but, according to it, almost anyone could work injury by resorting to praise:

The "Evil Eye" is of all other mischiefs most dreaded, and for a stranger to express particular admiration of a child, a horse, or any other valuable, is to bring on it or its possessor certain misfortune; this may, however, be averted by passing over the object a finger wetted with saliva, or by the equally efficacious charm of an open hand, either attached to the clothes as an ornament or tattooed on the skin.[24]

The Walloons entertain similar notions: "Une sorcière peut jeter un sort à un animal ou à un enfant, le rendre malade ou le fair périr, en faisant son éloge, en disant qu'il est beau, qu'il est bien portant, etc." [25]

There is a record of a Scottish woman who was alarmed when a visitor remarked to her: "You have a pretty, dear boy there." Forthwith the mother turned the child's face to her and began to spit in it as hard as she could to prevent any bad effect from the other woman's Evil Eye.[26]

[22] Frank G. Carpenter, *The Holy Land and Syria* (Garden City, New York, 1928), pp. 80–81. Cf. Elijūb Abēla, "Gebräuche in Syrien," *Zeitschrift des deutschen Palästina-Vereins*, 7(1884): 102. See also W. M. Thomson, *The Land and the Book* (New York, 1860), I: 219, and Edgar Thurston, *Omens and Superstitions of Southern India* (London, 1921), p. 116.

[23] Richard Pococke, *A Description of the East and Some Other Countries* (London, 1743), p. 181. See also E. W. Lane, *Manners and Customs of the Modern Egyptians* (London, n.d.), p. 259.

[24] G. F. Lyon, *A Narrative of Travels in Northern Africa in the Years 1818 19 and 20* (London, 1821), p. 52. I am informed that contemporary Arabs have a prayer which is said to take away the evil arising from praise not only of things present but also of those hoped for or desired.

[25] Eugène Monseur, *Le Folklore Wallon* (Brussels [1892]), pp. 90–91.

[26] Maclagan, p. 126. Cf. Mrs. Murray-Aynsley, *op. cit.* (see note 19), p. 140.

Since the powers that injure with the evil eye are so unsuspecting as to believe everything they hear, children may be protected by addressing to them words that are the opposite of endearments. An excellent example of such deceit occurs in Prosper Mérimée's *Colomba*,[27] which has a Corsican setting:

. . . "Va, coquine," disait-il, "sois excommuniée, sois maudite, friponne!" Brandaccio, superstitieux comme beaucoup de bandits, craignait de fasciner les enfants en leur addressant des bénédictions ou des éloges, car on sait que les puissances mystérieuses qui président à l'*Annocchiatura* ont la mauvaise habitude d'exécuter le contraire de nos souhaits.

The southern Slavs are likewise afraid to use expressions that show admiration:

Für „ein schmucker, prächtiger Junge, ein schönes Mädchen, ein gesundes Kind, ein tüchtiges Pferd, ein munteres Füllen" usw., sagt man gewöhnlich: „ein wahnwitziger, lahmer Junge, ein verunstaltetes Mädchen, ein verkehrtes (verwahrlostes) Kind, ein verwittertes Ross, ein schäbiges Füllen" usw.[28]

In accordance with the same principle the Rabbis of Palestine used to advise one to call a pretty son "ugly darky,"[29] and the Chinese have applied to their children the names "dog," "hog," "puppy," "flea," and so forth.[30] A guarded suggestion has been made that "our familiar habit of calling our children 'scamp' and 'rascal,' when we are caressing them, may be founded on a worn-out superstition of the same kind."[31]

PRAISE OF YOUTHS

Attractive boys and girls who were nearing adulthood were still young enough to fall victims to the evil eye. There is an interesting story about a very comely boy eighteen years old. His father, who owned a bath, refused to allow him to bathe in the presence of men because he feared their envy.[32] Since a point is made of mentioning

[27] Chapter 17. In his *Notes d'un voyage en Corse* (Paris, 1840), p. 188, Mérimée records the reply of Corsican mothers when their sons are praised: "Nun me l'annochiate."

[28] F. S. Krauss, *Volksglaube und religiöser Brauch der Südslaven* (Münster, i. W., 1890), p. 42.

[29] Rabbi Emil G. Hirsch, "The Evil Eye," *The Folk-Lorist*, 1 (1892): 73.

[30] S. Wells Williams, *The Middle Kingdom* (New York, 1883), I: 797.

[31] Story, p. 160. Calling people bad names is a rather common means of protection against the evil eye. See J. G. Frazer, *The Magic Art and the Evolution of Kings* (New York, 1935), I: 280.

[32] *Acta Joannis*, ed. Th. von Zahn (Erlangen, 1880), pp. 24–25. See Camp-

the beauty of the boy one is warranted in concluding that the father was afraid it might elicit a complimentary remark or an admiring glance. In the *Aethiopica* (3.7) Heliodorus tells us that a beautiful girl who had taken part in a procession became sick and retired to her room. Her condition is attributed to her having been seen by some spiteful eye.

In a quotation from a lost Roman play,[33] the *Setina* of Titinius, a lover exclaims: "Paula mea, amabo." At once he sees that his words may injure her, and hence he is quick to make an admonition: "Pol tu ad laudem addito praefiscini." The purpose was, we are told, "ne puella fascinetur."

PRAISE OF ADULTS

The blighting power of praise was feared by adults also. Those who saw the beautiful hetaera Laïs would make sacrifice, and in the midst of their wonderment would take the additional precaution of praying to the gods and exclaiming, *ἀπίτω φθόνος τοῦ κάλλους! ἀπίτω βασκανία τῆς χάριτος* (Aristaen., *Epp.* 1.1).[34] The peril of praise to men of modern Greece is exemplified in a striking story collected by a student of modern Greek folklore:

> . . . I have heard of an ancient dame of Salonica who had the reputation of possessing an evil eye. Many of her achievements were whispered with becoming awe. One day, it was said, as she sat at her window, she saw a young man passing on horseback. He seemed to be so proud of himself and his mount that the old lady . . . could not resist the temptation of humbling him. One dread glance from her eye and one short cry from her lips: "Oh, what a gallant cavalier!" brought both horse and horseman to their knees.[35]

The Gypsies, who are of a passionate nature, have deliberately employed praise as a means of inflicting injury:

> Iskander, isolated, haughty, was sad, angry, and cruel. He asked for neither counsel nor advice, and listened only to the flatterers who chanted his growing megalomania. Ben Sasra understood.
>
> "Their chants of praise are funeral chants. No man could outlive such praise. Our books say: Praise is deadly. There existing no material weapon to destroy Iskander, the Indians are using the most deadly spiritual one: praise."[36]

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bell Bonner, "Demons of the Bath," *Studies Presented to F. LL. Griffith* (London, 1932), pp. 203–208.

[33] Charisius, *Inst. Gram.* Liber II, in H. Keil, *Grammatici Latini*, I: 212.

[34] Similar examples of the fear of praise may be found under the headings "Excessive Praise" (pp. 588–589) and "Moderation in Praise . . ." (pp. 589–590).

[35] Abbott, pp. 145–146.

[36] K. Bercovici, *Alexander* (New York, 1928), p. 266.

German Jews of a half century ago believed that dire consequences followed the bestowal of praise: "Il faut éviter de vanter les qualités de ceux qu'on aime; sinon on pourrait leur faire perdre ces qualités ou même occasionner leur mort." [37]

SELF-FASCINATION

In ancient Italy it was risky for a man to say nice things about himself, for he could fascinate himself, as Plautus shows. In the *Rudens* (458–461) a slave who flatters himself because of his skill in drawing water from a well suddenly recalls the peril of such utterances and exclaims *Praefiscine!* In the *Asinaria* (491–493) a slave takes the precaution of saying *Praefiscini* before he mentions his own uprightness and good reputation. An illuminating passage occurs in the *Florida* (16) of Apuleius: "To meet with the favor of the people, to please the senate, to gain the approval of officers and leaders — I would speak without bewitchment (*praefiscine dixerim*) — in some measure has been my lot."

Self-esteem may be dangerous even though not manifested in words. Narcissus felt a consuming passion for the beautiful reflection of himself in a pool and so pined away and died (Ovid, *Met.* 3.402–510), but perhaps this was not fascination. A certain Eutelidas, however, did bewitch himself when he was enravished by his own beauty (Plut., *Mor.* 682B), and it was believed that young children might fascinate themselves by the reflection of their own gaze (*ibid.* 682F). Theocritus (6.34–39) represents Damoetas as spitting thrice upon his breast when he finds beautiful a reflection of himself in the water.

There is a good modern example of self-fascination, for a story is told of a Sicilian with an evil eye so powerful that he bewitched himself on accidentally catching sight of himself in a mirror.[38] According to an English superstition recorded seventy years ago, a bride who wished to take a last admiring look into a mirror after completing her toilette left one hand without a glove.[39] Possibly the lack of perfection in her attire had a protecting effect.

[37] J. Tuchmann, "La Fascination," *Mélusine*, 4 (1888–89) : 253. Cf. D. S. Weissenberg, "Kinderfreud und -leid bei den südrussischen Juden," *Globus*, 83 (1903) : 316.

[38] G. Pitrè, *Usi e costumi, credenze, e pregiudizi del popolo siciliano* (Palermo, 1889), IV : 238. Cf. Seligmann, I : 179.

[39] *Chambers's Journal of Popular Literature, Science, and Arts*, 48 (1871) : 233

PRAISE AND ILL HEALTH

Even when self-adulation does not cause self-fascination it may bring punishment from another source, as is shown by a Hungarian story: "Well, there is no doubting it, pretty little Helen got overlooked, but only because she came to believe that she was so pretty that everybody kept looking at her, and her only. She developed a perpetual headache." [40]

The most common results of praise, even though not bestowed by one with the evil eye, are sickness and ill health. Remarks about well-being are tantamount to praise of one's health, and they have been feared in many parts of the world.

In one of his letters Pliny the Younger (*Epist.* 5.6.45–46) sets forth the charms of his Tuscan villa. He says that he is unusually strong in both mind and body. Never have the members of his household enjoyed better health. He has not lost a single one of those whom he brought with him. Then, becoming frightened, he exclaims: "Venia sit dicto." It is hard to tell whether Pliny was praising or boasting, but such words concerning health were an entirely adequate cause for alarm. The following striking parallel is taken from an interesting collection of West Indian superstitions dated 1875:

> The feeling is by no means uncommon that to talk much of the health of a family, is a way to bring sickness on them. In the course of pastoral visitation, the clergyman will perhaps say, in a house where there is a large family, that he never has occasion to go to that house for visitation of the sick, so healthy is the household. He will be respectfully, but very decidedly asked not to speak too much about it, as it has been noticed that if this be done, sickness comes upon the family soon after.[41]

A rather similar idea has been recorded from the Orkneys:

> When a healthy child suddenly becomes sickly, and no one can account for the change, the child is said to have been "forespoken." Or when a stout man or woman becomes hypochondriac, or affected with nervous complaints, he or she is "*forespoken.*" Some one has perhaps said "He's a bonny bairn," or "Thou ar' lookin' well the day;" but they have spoken with an *ill tongue*. They have neglected to add, "God save the bairn," or, "Safe be thou," &c.[42]

[40] Margit Luby de Benedekfalva, "Treatment of Hungarian Peasant Children," *Folk-Lore*, 62 (1941): 112.

[41] Charles J. Branch, "West Indian Superstitions," *The Contemporary Review*, 26 (1875): 770–771.

[42] *Notes and Queries*, I, 10 (1854): 221.

An English writer states that "We need not go out of England to know that many people would rather you said anything to them than 'How well you are looking.'"[43] We find Hotspur exclaiming:

> No more, no more; worse than the sun in March,
> This praise doth nourish agues.[44]

In *Far from the Madding Crowd* (Chap. 15) Thomas Hardy makes effective use of the superstition that it is unlucky to praise one's health. On asking a rustic friend how he is Gabriel Oak receives the cautious reply: "Oh, neither sick nor sorry, shepherd; but no younger."[45] This accords with German folk belief: "Spricht Jemand von seiner, oder eines Anderen Gesundheit oder Glück, so sagt er dabei dreimal 'unberufen,' damit nicht Gesundheit in Krankheit, Glück in Unglück sich wende."[46]

In this general connection the second stanza of Poe's "Lenore" is pertinent:

> "Wretches, ye loved her for her wealth and hated her for her pride,
> And when she fell in feeble health, ye blessed her — that she died!
> How *shall* the ritual, then, be read? the requiem how be sung
> By you — by yours, the evil eye, — by yours, the slanderous tongue
> That did to death the innocence that died, and died so young?"

More or less similar examples may be found much farther afield. Among the superstitious people of Bombay a person who falls ill after having been praised is said to be a victim of the evil eye.[47] The Malays believe that "it is unlucky to remark on the fatness and healthiness of a baby, and a Malay will employ some purely nonsensical word, or convey his meaning in a roundabout way, rather than incur possible misfortune by using the actual word 'fat.' '*Ai bukan-nia poh-poh gental budak ini*' ('Isn't this child nice and round?') is the sort of phrase which is permissible."[48]

[43] V. S. Lean, *Collectanea* (Bristol, 1902–04), II: 475.

[44] *I Henry IV*, IV.i.111–112.

[45] See also J. W. Wickwar, *Witchcraft and the Black Art* (London, n.d.), p. 72.

[46] *Zeitschrift für Ethnologie*, 15 (1883): 90. See also Lean, *op. cit.* (see note 43), II: 466; Angelo S. Rappoport, *The Folklore of the Jews* (London, 1937), p. 77.

[47] R. E. Enthoven, *The Folklore of Bombay* (Oxford, 1924), p. 229.

[48] W. E. Maxwell, "The Folklore of the Malays," *Journal of the Straits Branch of the Royal Asiatic Society*, 7 (1881): 27–28. Other references are: an anonymous article, "The Evil Eye," *The Celtic Magazine*, 12 (1887): 415–416; Borrow, *op. cit.* (see note 10), pp. 118–119; J. C. Lawson, *Modern Greek Folklore and Ancient Greek Religion* (Cambridge, 1910), pp. 9–10; Maclagan, pp. 52, 53, 76, 77, 118, 127; Mrs. Murray-Aynsley, *op. cit.* (see note 19), p. 144; A. Polson,

THE DISPLAY OF AFFECTION

The manifestation of deep love or affection, especially for a child, is a kind of admiration, and may prove as deadly, but the danger comes chiefly from the jealousy of the gods. An informative passage occurs in the *Epictetus* (3.24.84–85) of Arrian:

> Whenever you grow attached to something, do not act as though it were one of those things that cannot be taken away, but as though it were something like a jar or a crystal goblet, so that when it breaks you will remember what it was like, and not be troubled. So too in life; if you kiss your child, your brother, your friend, *never allow your fancy free rein, nor your exuberant spirits to go as far as they like,* but hold them back, stop them, just like those who stand behind generals when they ride in triumph, and keep reminding them that they are mortal.[49]

The same general idea occurs in Euripides (*Alc.* 1133–1135). As Admetus showed his deep love for his wife, whom he expected never to see again, Heracles becomes somewhat fearful and says: "You have her. May there be no jealousy from any of the gods."

In Ian Maclaren's story of "Domsie" in *Beside the Bonnie Brier Bush* the following reflections are addressed to the mother of a boy who, after winning high honors in school and being much praised by relatives and others, had come home to die:

> Ay, ay, it's a sair blow aifter a that wes in the papers. I wes feared when I hear o' the papers: "Lat weel alane," says I to the Dominie; "ye 'ill bring a judgment on the laddie wi' yir blawing." But ye micht as well hae spoken to the hills. Domsie's a thraun body at the best, and he was clean infatuat' wi' George. Ay, ay, it's an awfu' lesson, Marget, no to mak' idols o' our bairns, for that's naethin' else than provokin' the Almichty.
>
> It was at this point that Marget gave way and scandalized Drumtochty, which held that obtrusive prosperity was an irresistible provocation to the higher powers, and that a skilful depreciation of our children was a policy of safety.

Another good example of the danger of loving intensely may be found in Kipling's story "Without Benefit of Clergy,"[50] in which a

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Our Highland Folklore Heritage (Dingwall and Inverness, 1926), pp. 114–116; Rappoport, *op. cit.* (see note 46), pp. 72–78; Story, p. 159; J. Tuchmann, "La Fascination," *Mélusine,* 3 (1886–87): 412.

[49] W. A. Oldfather's translation in the Loeb Classical Library. The italics are mine.

[50] Chap. 3. The story is one of those in *Mine Own People.* Similar incidents are recounted by Pearl S. Buck, *The Good Earth* (New York, 1931), p. 54, and *East Wind, West Wind* (London, 1931), pp. 181–182. See also James Napier, *Folk Lore: or, Superstitious Beliefs in the West of Scotland within This Century* (Paisley, 1879), pp. 34–35.

mother, desirous of guarding against the repetition of a fatal mistake, says:

> "It was because we loved Tota that he died. The jealousy of God was upon us," said Ameera. "I have hung up a large black jar before our window to turn the Evil Eye from us, and we must make no protestations of delight, but go softly underneath the stars, lest God find us out. Is that not good talk, worthless one?"
>
> She had shifted the accent of the word that means "blessed," in proof of the sincerity of her purpose. But the kiss that followed the new christening was a thing that any deity might have envied. They went about henceforth saying: "It is naught — it is naught," and hoping that all the powers heard.

The Germans, also, believe that they may bring disaster upon children by loving them too much. "Auch Kinder werden häufig krank gelobt. Starkes Loben gilt als verdächtig."[51] Uttering the word "unberufen" or "unbeschrien" protects children from the effects of endearments,[52] just as it does from those of excessive praise.

Failure of Egyptian Bedouins to take precautions after a display of affection brings serious results:

> Der Ausdruck „maschallah" lässt sich ungefähr mit „Gott verhüte Schlimmes" übersetzen und muss stets hinzugefügt werden, wenn man ein lebendes Wesen lobt. Sonst lässt sich Unheil oder Tod von dem betreffenden Menschen oder Tier nur dadurch abwenden, dass man sie dem unvorsichtigen Lobredner schenkt.[53]

PRAISE AND DIVINE JEALOUSY

As a rule, the gods reserved their hostility for the prosperous, the mighty, and the prideful among men, but praise might enter into the good fortune that they resented and counterbalanced by calamity.[54] I shall give three illustrations of the fear that happiness and success aroused among the ancients.[55]

In speaking to the elders of Argos Clytaemnestra, who has been reunited with Agamemnon, after his absence at Troy gives expression to her great joy and praises her husband rather fulsomely.

[51] L. Strackerjan, *Aberglaube und Sagen aus dem Herzogtum Oldenburg*[2] (Oldenburg, 1909), I: 374.

[52] Seligmann, I: 192–193; *Handwörterbuch des deutschen Aberglaubens,* I: 1097; Schmidt, p. 579.

[53] R. T. K., "Unter den Beduinen der ägyptische Wüste," *Globus*, 75 (1899): 193.

[54] See, for example, the references given on page 131 of the article by Canter (see note 4).

[55] I do not have space to discuss the subject of praise and the gods. It is closely tied up with notions about ὕβρις, a subject treated in many articles.

When she realizes how laudatory she has been she exclaims: **φθόνος δ' ἀπέστω** (Aesch., *Agam.* 904). Agamemnon seems even more alarmed than she is, and he warns her that for praise to be seemly it must come from the lips of others. He beseeches her not to make his path subject to jealousy by strewing it with carpets (*ibid.*, 916–922). In the *Rhesus* (342–345) of Euripides the chorus entreats Adrasteia, the child of Zeus, to ward off the jealousy caused by their uttering whatever is dear to their hearts.

An overenthusiastic reception of an official was tantamount to praise of the kind that aroused the envy of the gods. On one occasion when Germanicus Caesar, the grandson of the deified Augustus, was in Alexandria the cordial greetings of the populace greatly frightened him.[56] He deprecated their acclamations of him as a god and threatened to appear before them less frequently unless they restrained themselves. According to Sir Walter Scott, Gustavus Adolphus was equally perturbed by the worship of a throng as he rode through the streets of Nuremberg. The novelist puts these words into the mouth of the great general: "If you idolise me thus like a god, who shall assure you that the vengeance of Heaven will not soon prove me to be a mortal?"[57]

PRAISE OF CATTLE

So far as I am aware, Pliny the Elder and Aulus Gellius are the only classical authors who tell us that praise kills animals, but the shepherd in Vergil, *Eclogues* 3.103, may have been thinking of an admiring glance when he said: "Nescio quis teneros oculus mihi fascinat agnos."[58] Later examples of deadly commendation of beasts are easy to find.

Early in the thirteenth century Gervase of Tilbury, in his *Otia Imperialia*,[59] written to amuse a king, advises the reader not to marvel that the words of the wicked can kill animals. He says that in the kingdom of Arles there was a man whose praise was so infective that a horse or any other domestic animal which he noticed in this way either died or was in danger of death. In the sixteenth

[56] F. Preisigke, *Sammelbuch griechischer Urkunden aus Ägypten* (Strassburg, 1913), Vol. I, No. 3924.

[57] *A Legend of Montrose*, Chap. 14.

[58] Cf. Servius *ad loc.*: "Et per transitum, pulchrum se pecus habere significat quod meruit fascinari."

[59] Page 37 in the edition of Felix Liebrecht (Hannover, 1856).

century a witch of Savoy who was arrested at the door of a stable in which someone was putting a yoke on oxen exclaimed: "Ho! les gaillards bœufs, Dieu les gard!" One of them died soon after.[60] In Oldenburg a witch has been known to kill a pig merely by saying: "Das ist ja ein schönes Schwein." [61]

Similar beliefs have flourished in Scotland, where the most casual, innocent, or commonplace expression of admiration of an animal has been dire enough to cause sickness or death, for example: "a splendid sow," "a grand cow," "Hasn't the cow the big udder?" "You are a bonnie cow," "You [a horse] have got fine limbs."[62]

Just as a man may injure himself by self-admiration, so he may harm his own animals by "thinking too highly of them." [63] A certain Scottish farmer had to be kept in the house "when his own cattle were being taken in from pasture, in case by admiring them he might be the means of doing them an injury." [64] In a work dated 1691 we have a Scottish parson's word for it that a man in his parish killed his own cow by commending its fatness, and even "shot a Hair with his Eyes, having praised its swiftness, (such was the Infection of ane evill Eye)." [65]

The efficacy of belittling remarks as a means of warding off the evils that attend praise is beautifully illustrated by a Scottish story:

> . . . A man ploughing, who thought very well of his horses, said to his master on seeing another he knew approaching, "Here comes ——, and he will ruin both the horses if he can, for he has the Evil Eye." His master said, "I'll tell you what you will do, and if you do it he can do the horses no harm. When he begins to

[60] J. Tuchmann, "La Fascination," *Mélusine*, 5 (1890–91): 230. Cf. P. Sébillot, *Le Folklore de France* (Paris, 1904–07), 3: 126. See also the quotation from Monseur on page 574.

[61] Strackerjan, *op. cit.* (see note 51), I: 374.

[62] Maclagan, pp. 12, 56, 8 (cf. 78), 168, 62, respectively.

[63] Maclagan, pp. 71–72.

[64] Maclagan, p. 40. In the same work may be found examples of dire results from praising chickens (pp. 79, 88), ducks (p. 66), pigs (pp. 12, 79), cows (pp. 8, 56, 71, 77, 85, 168, 206), horses (pp. 39, 62, 63, 74, 88), cattle and animals in general (pp. 70, 72, 87, 114). Cf. Blunt, *op. cit.* (see note 13), pp. 242–243; Carpenter, *op. cit.* (see note 22), p. 81; Miss A. Goodrich-Freer, "The Powers of Evil in the Outer Hebrides," *Folk-Lore*, 10 (1889): 266–267; A. Goodrich-Freer, *Outer Isles* (Westminster, 1902), pp. 236–237; Gregor, p. 8; Lane, *op. cit.* (see note 23), p. 259; Roswell Park, *The Evil Eye, Thanatology, and Other Essays* (Boston, 1912), p. 11.

[65] Robert Kirk, *The Secret Commonwealth of Elves, Fauns, and Fairies.* The Text by Robert Kirk . . ., 1691. The Comment by Andrew Lang . . ., 1893 (London, 1893), pp. 54–55.

praise either or both just begin to run them down, and be sure you say as much against them as he shall say for them." He of the Evil Eye came up, and commencing with "What a fine pair of horses you have," went on to enumerate their good points. The servant objected that they looked better than they were, that their looks were the best of them, and for every point in their favour the other mentioned, the lad said something to counterbalance it. The other began to show signs of impatience, and went on his way not very well pleased with the way his opinions of the horses had been disputed. "Well done, you have saved the horses," said the master. "Did I do right?" said the lad. "Yes, indeed, you could not have said more than you have said." [66]

Among the Scottish people, too, we find saliva employed as a protection against praise:

If a person came and saw a cow or other creature belonging to you, and he began to praise it, *e.g.* if he were to say, *tha ùth mór aig a' bhoin*, "the cow has a big udder," or anything similar of a complimentary nature, this act of praising was called *aibhseachadh;* and as it might lead accidentally to *gonadh*, or evil eye, or wounding of the cattle, as a preventative it was customary to say to the person making the complimentary remarks: *Fliuch do shūil* = "wet your eye." This wetting of the eye was generally performed by moistening the tip of the finger with saliva, and moistening the eye with it thereafter.[67]

According to a work published in 1722, natives of backward districts of Ireland were equally afraid of praise bestowed upon their animals: "If one praise a horse, or any other creature, he must cry, God save him, or spit upon him; and if any mischief befalls the horse within three days, they find out the person who commended him, who is to whisper the Lord's prayer at his right ear." [68] A somewhat earlier writer tells us that "the wild Irish spat upon a horse when they praised it." [69]

An offer to purchase an animal is a compliment — a dangerous one. In English lore, "It is very unlucky to bid a price for an animal, such as a cow, pig, or horse, when it is not for sale, for if this is done the animal is sure to die." [70] Such a fate befell a horse owned by a Scot. "A man taking a valuable horse from the west

[66] Maclagan, p. 117.

[67] G. Henderson, *Survivals in Belief among the Celts* (Glasgow, 1911), pp. 27–28. Cf. Goodrich-Freer, *Outer Isles* (see note 65), p. 237.

[68] Quoted by William Camden, *Britannia* (London, 1722), II: 1421.

[69] Aubrey, *op. cit.* (see note 17), p. 42.

[70] E. M. Wright, *Rustic Speech and Folk-Lore* (London, 1913), p. 219. Cf. Elworthy, pp. 12–13. I once roomed in an attractive bungalow which caught the fancy of a passer-by. He stopped and asked the owners whether it was for sale. They were unwilling to sell, but the stranger asked them to set a price. They refused to do so, and my landlady, now much wrought up, became almost frantic in her effort to prevent him from making an offer.

coast of Kintyre to Tarbert, was after leaving Musadale, offered a considerable sum for it. He said he would not, could not sell the beast, and though the offer was raised to sixty pounds, he still refused and went on his way. Before he reached Tayinloan the horse fell dead on the road." [71] In Palestine a man who is asked whether he will sell a horse must reply "Yes," but he puts a prohibitive price upon it. "At such times he usually requests the would-be purchaser to stop thinking of his horse for fear it may bring misfortune." [72]

PRAISE OF VEGETATION

Modern lore provides parallels that enable us to understand quite readily the ancient belief that certain families in Africa could blight trees with their praise. In the Greece of today a blooming garden may stir envy into action,[73] but an experience of an English consul's daughter in Turkey gives us a better idea of the way praise may destroy a tree. Her account is as follows:

> I knew a lady at Broussa [Brusa] whose eye was so dreaded as to induce her friends to fumigate their houses after she had paid them a visit. She happened to call upon my mother one evening when we were sitting under a splendid weeping willow-tree in the garden. She looked up and observed that she had never seen a finer tree of its kind. My old nurse standing by heard her observation, and no sooner had our visitor departed than she suggested that some garlic should at once be hung upon it or it would surely come to grief. We all naturally ridiculed the idea, but as chance would have it, that very night a storm uprooted the willow. After this catastrophe the old woman took to hanging garlic everywhere, and would have ornamented me with it had I not rebelled.[74]

In Scotland, too, it was believed that crops were exposed to the perils of forespeaking (or excessive praise).[75]

Among the Romans untrue remarks were made about the condition of first fruits. They would say: "These are old; we desire other, fresh, fruits." [76] What happens when good fruit receives its due may be illustrated by a modern story with a setting on the Greek island of Sikinos, in the Cyclades: "Old Kortes, the ex-demarch, told me that he had an apple tree covered with lovely fruit; some one with the evil eye went past and said, 'Oh, what lovely apples!' Two hours afterwards they returned that way, and

[71] Maclagan, p. 88. [72] Carpenter, *op. cit.* (see note 22), p. 81.
[73] Abbott, p. 140; Schmidt, p. 578.
[74] Blunt, *op. cit.* (see note 13), p. 242. [75] Gregor, p. 8.
[76] Pliny, *Nat. Hist.* 28.23: "Cur ad primitias pomorum haec vetera esse dicimus, alia nova optamus?"

found not a single apple on the tree, and basketfuls lying on the ground."[77]

The Greeks protect trees laden with fruit by a clove of garlic hung from their branches.[78] In parts of India people used to suspend an old shoe from the branches of a tree that bore beautiful blossoms or good fruit.[79]

There is an interesting English saying: "Previous to St. John's day we dare not praise barley."[80] Evidently young vegetation, like young children, was particularly susceptible to the dangers immanent in praise.

Just as belittling remarks served to protect children from the evil eye, just as ribald jests safeguarded the triumphing general,[81] and just as calling persons bad names saved them from harm,[82] so maledictions warded off peril from seeds that were intended to become flourishing crops. In order to insure a good growth of cumin the Greeks cursed and abused the seed while sowing it.[83] The Romans sowed rue to a similar accompaniment (Pallad. 4.9.14). Among the Cyprians ability to curse seems to have been almost a prerequisite to successful farming, for they spoke of "sowing curses."[84] Sometimes the Romans offered prayers that seeds might never come up (Pliny, *Nat. Hist.* 19.120). Raillery and abuse were believed at times to promote fertility,[85] but it seems clear that curses were also supposed to throw the maleficent powers off their guard, for they disdained to pay attention to anything inferior or despised.

PRAISE OF INANIMATE THINGS

In modern Greece inanimate objects, especially attractive ones, such as a new house, are liable to be injured by the evil eye.[86] Admiration called forth by "the rosy colour and the seductive smell"

[77] J. Th. Bent, *The Cyclades, or Life among the Insular Greeks* (London, 1885), p. 185.

[78] Abbott, p. 141.

[79] J. Tuchmann, "La Fascination," *Mélusine*, 8 (1896–97): 257.

[80] R. Inwards, *Weather Lore*[3] (London, 1898), p. 35.

[81] See, for example, Suet., *Julius*, 49.4 and 51.

[82] See note 31.

[83] Theophr., *Hist. Plant.* 7.3.3; 9.8.8; Plut., *Mor.* 700 F–701 A; Pliny, *Nat. Hist.* 19.120.

[84] Hesych. s.v. ἀρὰς ἐπισπεῖραι.

[85] J. G. Frazer, *Pausanias's Description of Greece* (London, 1898), III: 268.

[86] Abbott, p. 140; Schmidt, p. 578.

of a pie might bring about its immediate ruin.[87] A note at the end of *The Last Days of Pompeii*, by Bulwer-Lytton, tells how a Neapolitan lady became distracted when she heard a man with the evil eye praising her cap. Calling the contents of a churn of butter beautiful may make the butter scatter on the churn and become froth.[88] In Scotland praise of a plow has caused it to break into two parts.[89]

An old English saying urges one to "praise the day when it is over."[90] The German and Danish version is: "Praise a fine day at night."[91] Whatever may be the superstitious background of these adages they do remind us of Solon's admonition to Croesus not to admire the good fortune of a man while there is still time for it to change (Plut., *Solon* 27.5).

The Egyptians have shown great ingenuity in keeping things from being praised. "You order, for instance, a new boom for your boat, and when you go to see it, your heart sinks to find it with a splice, as though it had already been broken. Such a fine new boom, your dragoman tells you, would be sure to attract the Evil Eye, with direst consequences, and so the fates must be hoodwinked in this way."[92]

Giving a little present to one who admires an object counteracts his praise.[93] Neapolitans have even offered to give to guests possessions for which they have expressed a liking.[94]

FAIRIES AND PRAISE

In Ireland attractive children who are praised come to grief through the agency of fairies, as we may see from a story told by an old man of the Aran Islands:

> One day a neighbour was passing, and she said when she saw it on the road, "That's a fine child."
>
> Its mother tried to say, "God bless it," but something choked the words in her throat.

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[87] Abbott, p. 146. [88] Maclagan, p. 122. [89] Maclagan, p. 39.

[90] Thomas Wright, *Essays on Subjects Connected with the Literature, Popular Superstitions, and History of England in the Middle Ages* (London, 1846), I: 148.

[91] R. Christy, *Proverbs, Maxims, and Phrases of All Ages* . . . (New York and London, 1887), II: 430.

[92] S. H. Leeder, *Veiled Mysteries of Egypt and the Religion of Islam* (London, 1923), p. 40.

[93] Maclagan, p. 122.

[94] W. S. Walsh, *Handy-Book of Literary Curiosities* (Philadelphia, 1925), p. 347.

A while later they found a wound on its neck, and for three nights the house was filled with noises.

"I never wear a shirt at night," he said, "but I got up out of my bed, and all naked as I was, when I heard the noises in the house, and lighted a light, but there was nothing to it."

Then a dummy came and made signs of hammering nails in a coffin.

The next day the seed potatoes were full of blood, and the child told his mother that he was going to America.

That night it died, and "Believe me," said the old man, "the fairies were in it." [95]

"God's name destroys the power of the fairies," and it appears in protecting words. "*Mămdeud* (God save you), *Slaunter* (your good health), and *Boluary* (God bless the work), should be said respectively when you enter a house, when you drink anything, and when you come to people at work; such expressions show that you have no connection with the fairies and will not bring bad luck." [96]

From a Scottish source we learn that the danger from the fairies was greater when a baby was pretty and its beauty charmed all who saw it. [97]

EXCESSIVE PRAISE

In the quotation from Aulus Gellius (p. 569) emphasis is laid upon the lavish bestowal of praise. This aspect of my subject is well illustrated in the plays of Euripides, who was thoroughly acquainted with Greek popular lore. He makes Orestes say to Pylades (*Orest.* 1161–1162): "I shall cease praising thee, since there is some grief even in this, praising too much." Iolaus knows that excessive praise arouses envy (ἐπίφθονον), for he has often been heavy of heart because of it (*Heracl.* 202–204). An illuminating comment on this subject was addressed to Achilles by Clytaemnestra (*Iph. in Aulis*, 980–981): "The good somehow hate those who praise if they praise to excess."

Tertullian (*De Virg. Vel.* 15) is almost as explicit as Euripides. After making a general statement to the effect that there existed among the *ethnici* something to be feared which they called *fascinum* he explains that it was the unhappy result of unbounded praise or glory ("infeliciorem laudis et gloriae enormioris eventum"). Another interesting record of this idea is to be found in Vergil (*Ecl.* 7.27–28):

[95] John M. Synge, *The Aran Islands* (Dublin, 1911), p. 5.

[96] G. H. Kinahan, "Notes on Irish Folk-Lore," *Folk-Lore Record*, 4: 104, 112.

[97] Compare a story recorded by Napier, *op. cit.* (see note 50), pp. 40–41.

Aut si ultra placitum laudarit, baccare frontem
Cingite ne vati noceat mala lingua futuro.

Classical ideas about unrestrained praise would be readily understood in parts of Scotland, for a book on Scottish lore says: "Praise beyond measure — praise accompanied with a kind of amazement or envy — was followed by disease or accident." [98] Meeting great praise with praise still more extravagant was a homeopathic remedy practiced by Scotsmen.[99]

MODERATION IN PRAISE OR ABSTENTION FROM IT AS A MATTER OF COURTESY

The words I have quoted from Euripides (p. 588), "I shall cease praising thee, since there is some grief even in this, praising too much," show that a considerate Greek refrained from dangerous commendation of a friend. As we have seen (p. 576), a Roman lover might tell his beloved to say *Praefiscini* to avert the consequences of unguarded praise. Doubtless *Praefiscini dixerim*, in addition to proclaiming the good intentions of the speaker,[100] also served to put the recipient of praise on his guard, so that he might use an antidotal formula for himself.[101] In some of the mountainous parts of Italy people have been known to say "Si mal occhio non ci fosse," by which they meant that the praise would be acceptable if sincere and unattended by envy.[102]

From a work dated 1546, by an Italian physician of Verona,[103] we learn that Italians who wished to praise someone would utter the safeguarding wish, "Verba nostra tibi non noceant." [104] We are informed that "A person who should wander through Italy, and especially through Southern Italy, praising all he saw, would soon come to be considered the most malevolent of men." [105]

[98] Gregor, p. 35. See also p. 8, and compare Hirsch, *op. cit.* (see note 29), p. 73: "The Jews also took precautions against 'beschreien,' — against praising beyond bounds person or object."

[99] Maclagan, p. 118; Adela Goodrich-Freer, *Outer Isles* (see note 65), p. 237; *Folk-Lore*, 10 (1889): 266.

[100] Dodwell, *op. cit.* (see note 18), II: 35.

[101] Elworthy, p. 33.

[102] Dodwell, as cited in note 100.

[103] Girolamo Fracastor, *De Sympathia et Antipathia Rerum.* I have taken the quotation from Vincentius Alsarius, *De Invidia et Fascino Veterum*, an interesting work which is reproduced by Graevius, *Thes. Antiq. Roman.*, XII: 889–899.

[104] *Of course, this is a translation from Italian into Latin, in which the text is written.*

[105] Walsh, *loc. cit.* (see note 94), p. 347.

Being sparing of commendation is a matter of courtesy in several parts of the world.[106] One writer goes so far as to say that ". . . it was a universally recognised rule of good manners and morals, that every one in praising another should be careful not to do so immoderately, lest he should fascinate even against his will." [107]

SUMMARY OF METHODS OF AVERTING EVILS ARISING FROM PRAISE

It has become evident that there are many ways of taking out insurance against the harmful effects of being praised. In this brief summary of them the numbers in parentheses refer to pages containing representative examples.

A sovereign remedy for praise already bestowed is saliva or spittle (p. 572),[108] to which the popular imagination ascribes many virtues.[109] Moistening the eye with saliva has been practiced in Scotland (p. 584). Other effective precautionary measures are skillful depreciation (p. 580), mock dispraisal (p. 575), and disparaging or belittling remarks (p. 571). Raillery and abuse have been employed to forestall the effects of praise (p. 586). Overpraising an object that has been lauded (p. 589) and setting a higher valuation upon things for which an offer has been made (p. 585) are homeopathic devices.

Certain safeguarding expressions such as *φθόνος δ' ἀπέστω* and *Praefiscini* were common among the Greeks and Romans (pp. 577, 582), and many parallels to them can be found in the lore of other nations.[110] At times the blessing of a deity is invoked (p. 588). The mere utterance of the word "garlic" may afford protection (p. 572) and, of course, garlic itself was a prophylactic, as was *baccar* in Roman times (p. 589). Giving gifts, or even making an offer to do

[106] Blunt, *op. cit.* (see note 13), p. 245; Lane, *op. cit.* (see note 23), p. 256; Elworthy, pp. 17, 32; Story, p. 159.

[107] Story, p. 156.

[108] Cf. Abbott, pp. 140–141; Schmidt, pp. 591–592.

[109] See, for example, J. E. Crombie, "The Saliva Superstition," *The International Folk-Lore Congress of 1891*, pp. 249–258; F. W. Nicolson, "The Saliva Superstition in Classical Literature," *Harvard Studies in Classical Philology* 8 (1897): 23–40; R. Selare, "A Collection of Saliva Superstitions," *Folk-Lore* 50 (1939): 349–366; J. Hastings, *Encyclopaedia of Religion and Ethics*, XI: 100–104.

[110] Seligmann, II: 365–367; Schmidt, pp. 581–582; J. Tuchmann, "La Fascination," *Mélusine*, 9 (1898–99): 105–106; Elworthy, p. 17; James Kelly, *A Complete Collection of Scotish Proverbs* (London, 1721), p. 120, No. 57.

so, is still another means of securing safety from the ill results of praise (p. 587).

Charms and talismans are often resorted to in an effort to ward off the evil eye (p. 586), and ornaments may be worn to divert attention from the wearers.[111] Parents may allow children to go unkempt [112] in order to escape the notice of the malign powers or even may dress boys in girls' clothes,[113] but I have no classical illustrations of these two devices. Presumably all methods effective against the evil eye have been and still are effective against praise.

The examples I have given show that both the ears and the eyes of the gods and other envious powers may be deceived. Several of these practices do not reflect credit upon the intelligence of the beings whose hostility is feared.

CONCLUSION

As we have seen, the ideas under discussion are widespread, and their similarity, even in the way praise operates to injure and destroy, is striking. The Latin countries naturally inherited some of these superstitions from the Romans, but he would be rash who would venture to state that they originated in a common center. The presence of geometric designs on vases made by nations separated by oceans is by no means proof of borrowing; it is, rather, evidence that nations may express themselves in the same way when they reach similar stages in their development. Envy of one's prosperous neighbors is far from being a rarity, and there is always someone who gloats over a failure. The immense continuing popularity of "Casey at the Bat" has been explained as due to its having caught the spirit of the mob, which likes to witness the downfall of the mighty. A prize fight in which a champion is likely to lose his crown always draws a big crowd. The versatility of a youthful film actor is said to have aroused marked dislike among some people because they "are appalled and offended by such assorted virtuosity." In *The Keys of the Kingdom*, by A. J. Cronin, we find these words put into the mouth of a priest who, apparently, was oblivious to the glories of this world: "Perhaps the greatest strain is thrown

[111] Abbott, p. 142.

[112] Lane, *op. cit.* (see note 23), pp. 57–58.

[113] See A. M. Spoer, "Simulated Change of Sex to Baffle the Evil Eye," *Folk-Lore* 37 (1926): 304: cf. *ibid.* 24 (1913): 385; Frazer, *op. cit.* (see note 85), II: 266; *idem*, *Adonis, Attis, Osiris* (London, 1914), II: 260–261.

upon our moral vision by the spectacle of another's success. The dazzle hurts us."

Numerous passages about *φθόνος* and *invidia* in the classical languages show that Greeks and Romans experienced difficulty in looking with equanimity upon the success of friends and countrymen and their rise to prominence and distinction.[114] Thessalian women stoned Laïs to death because they were envious of her beauty.[115] I am inclined to believe that the ancients were far more addicted to envy than we are.[116] Aeschylus (*Agam.* 832–837) goes so far as to declare that there are only a few men "in whom it is inborn to admire without envy a friend's good fortune. For the venom of malevolence settles upon the heart and doubles the burthen of him afflicted of that plague: he is himself weighed down by his own calamity, and repines at sight of another's prosperity." [117] The Romans often gave expression to similar ideas.[118] Since the gods were endowed by man with many of his own thoughts and characteristics, they, as well as human beings, nursed feelings of jealousy, chiefly of the mighty and the proud. Solon tells Croesus that anything in which the gods are concerned is full of jealousy and trouble.[119]

In the ancient world a man who wished to escape the perils attendant upon eminence and success would have done well to follow the example of Timoleon, a member of one of the noblest families of Corinth. He never allowed a proud or boastful word to pass his lips. When he heard his praises heralded for a great achievement he

[114] In the brief *Lives* of Cornelius Nepos we find many records of the actual or supposed influence of envy (*invidia*) upon the careers of great men. See *Alcibiades*, 4, 7; *Chabrias*, 3; *Cimon*, 3; *Datames*, 5; *Dion*, 6, 9; *Epaminondas*, 7; *Eumenes*, 7, 10; *Themistocles*, 8; *Timoleon*, 1 (". . . nonnulli enim laesam ab eo pietatem putabant et invidia laudem virtutis obterebant)"; *Timotheus*, 3; *Thrasybulus*, 4.

[115] Plut., *Mor.* 768 A.

[116] They carried the fear of it even to the grave. Cf. *CIL*, IX: 2043: "Hic tumulus parvus nihil habet invidiae nec nimium iactat."

[117] Translation of H. W. Smyth in the Loeb Classical Library.

[118] Cf. "Est enim hoc commune vitium magnis liberisque civitatibus ut invidia gloriae comes sit et libenter de eis detrahant quos eminere videant altius . . ." (Nepos, *Chabrias*, 3); "Quam sit adsidua eminentis fortunae comes invidia altissimisque adhaereat . . ." (Vell. Paterc. 1.9.6); "Numquam eminentia invidia carent" (*ibid.*, 2.40.4); "Verum nulla tam modesta felicitas est quae malignitatis dentes vitare possit" (Val. Max. 7.7, Ext. 2). Many examples like these have been collected by Atto Vannucci, *Proverbi Latini* (Milan, 1879), p. 99.

[119] Herod. 1.32: τὸ θεῖον πᾶν ἐὸν φθονερόν τε καὶ ταραχῶδες.

humbly announced that he was grateful to the gods for making him the human instrument to carry out their wishes.[120]

In closing I quote a remarkable generalization made by Professor W. G. Sumner, in *Folkways*,[121] on the basis of comparatively scanty material: "It follows from the notion of the evil eye that men should never admire, praise, congratulate, or encourage those who are rich, successful, prosperous, and lucky. The right thing to do is to vituperate and scoff at them in their prosperity. That may offset their good luck, check their pride, and humble them a little."

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[120] Nepos, *Timoleon*, 4.
[121] P. 515. Boston, Ginn & Co., 1913.

HISTORY AND POLITICAL SCIENCE

THE ORIGIN OF THE BALFOUR DECLARATION

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THROUGHOUT the years which have elapsed since the end of the first World War Palestine has proved to be one of Great Britain's most serious problems of empire — a problem second only, perhaps, to the India question. In Palestine the hopes of the Jews, the fears of the Arabs, and the desires of the British have boiled and bubbled in a witches' caldron that has brewed not only toil and trouble for the British, but constant enmity between the Arabs and the Jews. This enmity has risen at times, as in 1936, to peaks of fratricidal bloodshed — fractricidal, because the Arabs and the Jews are, after all, both Semitic peoples. These Palestine "disturbances," as British officialdom euphemistically calls them even though they may be full-fledged civil wars, have cost the lives of many hundreds of Arabs and Jews, not to mention British lives lost in the day-to-day task of preserving public order.

Much of the Palestine problem is rooted in the famous Balfour Declaration, in questions relating both to its scope and to its execution. The Balfour Declaration is the *official statement of policy* toward the Zionist movement issued by the British Government during the darkest days of the first World War. It promised to the Jews the support of the British Government in the establishment of what was called a "Jewish National Home" in Palestine. In investigating almost any Palestine problem of the period between the two world wars one turns as naturally to the Balfour Declaration as the student of American government, in considering any basic problem of American political institutions, turns to the Constitution of the United States, or the student of international organization, to the League of Nations Covenant.

An understanding of the Declaration is, therefore, essential to an understanding of most Palestine political problems. Similarly, in order to be able to interpret the Balfour Declaration — which is by no means a model of legally precise language — it is useful to in-

vestigate in some detail the drafting of the Declaration and the reasons which impelled the British Government to sponsor a Jewish national home in Palestine.

Although the Balfour Declaration was announced in November of 1917, the Zionist movement itself began many years earlier. Even the renowned Zionist essay, *Judenstaat*, by Theodor Herzl,[1] published in 1896, had numerous predecessors.[2] In his book Herzl set forth in compelling language the case for an independent Jewish state. If historically it is inaccurate to say that Zionism began with Herzl, it cannot be doubted at any rate that it was Herzl who made Zionism politically significant and so flung the Zionist movement into the arena of world politics. The impetus of Herzl's writing and personality led to the convening of the First World Zionist Congress, in Basle, Switzerland, in 1897.

Herzl himself was much more interested in the problem of the creation of a Jewish state than in the location of that state.[3] The Basle Congress quickly made both problems of like importance. The Congress connected Zionism permanently with a return of the Jews to Palestine, formally declaring: "The aim of Zionism is to create for the Jewish people a legally assured home in Palestine."[4]

[1] See Jacob De Haas, *Theodor Herzl* (New York: Brentano's, 1927), 2 vols.

[2] On the Zionist movement see, among many others: Nahum Sokolow, *History of Zionism, 1600–1918* (London: Longmans, Green and Co., 1919), 2 vols.; Leonard Stein, *Zionism* (2d ed.; London: Paul, Trench, Trubner and Co., 1932), 206 pp.; Richard Gottheil, *Zionism* (Philadelphia: Jewish Publication Society of America, 1914), 258 pp.; *Zionism*, No. 162 of the handbooks prepared under the Historical Section of the Foreign Office, in Vol. X of *Peace Handbooks* (London: H. M. Stationery Office, 1920); and Shoshanna Harris Sankowsky, *Short History of Zionism* (3d ed.; New York: Avukah, 1939), 88 pp. For a description of the Zionist movement with special reference to the Balfour Declaration see Mrs. Edgar (Blanche E. C.) Dugdale, *The Balfour Declaration: Origins and Background* (London: Jewish Agency for Palestine, 1940), pp. 7–20. A fine bibliography on Zionism, arranged by topics, is to be found in Joseph S. Shubow (ed.), *The Brandeis Avukah Annual of 1932* (Boston: Stratford Co., 1932), pp. 733–805.

[3] In his *Judenstaat* Herzl considers two areas — Argentina and Palestine. See the English translation *A Jewish State* (New York: The Maccabaean Publishing Co., 1904), pp. 27–29. See also Dugdale, *op. cit.*, p. 18.

[4] Fannie Fern Andrews, *The Holy Land under Mandate* (Boston: Houghton Mifflin Co., 1931), I, 313. The German text reads: "Der Zionismus erstrebt für das jüdische Volk die Schaffung einer öffentlich-rechtlich gesicherten Heimstätte in Palästina." Ernst Marcus, *Palästina — ein werdender Staat*, in *Frankfurter Abhandlungen zum Modernen Völkerrecht*, Heft 16 (Leipzig: Noske, 1929), p. 319.

Between 1897 and the outbreak of the first World War ten other Zionist congresses were held. During this period the Zionists clung to their demand for a return of the Jews to Palestine. The Seventh Zionist Congress (1905) rejected a British offer of land for a Jewish colony in the British East Africa Protectorate.[5] This decision resulted in the defection of a minority under Israel Zangwill; but the Zionist organization dedicated itself the more irrevocably to a Jewish return to Palestine and to Palestine alone.

Thus by 1914 the Zionists were firmly determined to reëstablish their Jewish national life in Palestine and not elsewhere. And it was the outbreak of the war and particularly the entrance of Turkey into the war that gave the Jews their first real opportunity; for the defeat of Turkey would undoubtedly result in the removal of the Holy Land from Turkish sovereignty.[6] Military events — the British defense of the Suez Canal and the British campaign in Palestine under General Allenby — made it clear that the focal point of the Zionist efforts to gain support for their program of a Jewish return to Palestine would be Great Britain. Accordingly, the Zionists, led by Dr. Moses Gaster, Dr. Joseph Hertz, Dr. E. W. Tschlenow, Dr. Nahum Sokolow, and particularly Dr. Chaim Weizmann,[7] set about promoting the Zionist program among British intellectuals and government officials.[8]

[5] Andrews, *op. cit.*, I, 316.

[6] See Dugdale, *Arthur James Balfour* (London: Hutchinson and Co., Ltd., 1930), II, 222; and *Report of the Executive of the Zionist Organization to the Twelfth Zionist Congress (1921), Political Report* (hereafter cited as *Zionist Executive Reports*, XII [1921], *Political Report*), p. 7.

[7] See "Dr. Chaim Weizmann," chap. xxxv in John Gunther, *Inside Asia* (New York: Harper and Bros., 1939), pp. 560–571, for interesting sidelights on Weizmann's life and work.

[8] *Zionist Executive Reports*, XII (1921), *Political Report*, p. 7. The account of the Zionist negotiations with the British Government leading to the Balfour Declaration has never been officially published. The Peel Commission reported, however: "We have been permitted to examine the records . . . ." *Palestine Royal Commission Report*, Cmd. 5479 (1937) (hereafter cited as *Peel Report*), p. 24. The best single source on the negotiations is the political report made by the executive of the Zionist organization to the Twelfth Zionist Congress, in 1921 (*Zionist Executive Reports*, XII [1921], *Political Report*, pp. 10 ff.). The section in the present article on the Zionist work in England and the conversations leading to the Balfour Declaration is taken, unless otherwise indicated, from this source or from Sokolow, *op. cit.*, II, 42–54. A thorough treatment of the origin of the Balfour Declaration available for those to whom Hebrew is not a linguistic bar is found in M. Gelber, *Toldot Hazharat Balfour* (Jerusalem: Zionist Executive, 1939), 360 pp.

In these efforts the Zionists were aided by a stroke of good fortune brought about in large part by the trend of the war. A group of Manchester leaders, headed by C. P. Scott, editor of the *Manchester Guardian*, and Herbert Sidebotham, then on the staff of the *Guardian*, came to support the Zionist program. Their arrival at this stand was not primarily due to an interest in Zionist ambitions toward Palestine. Rather, a rational analysis of the British position in the Middle East led them to a belief in the coincidence of British and Jewish interests in Palestine. The view of the Manchester group — and this was its connection with military events — was that the imperial defense needs of Britain, with particular reference to the security of the Suez Canal, could best be served by the creation in Palestine of a Jewish state friendly to Britain.[9] In an effort to translate this view into a governmental policy these men in the spring of 1916 submitted a lengthy memorandum to the British Foreign Office.[10] Later on they organized the British Palestine Committee, termed by the Zionists "an important ally of Zionism." [11] This Committee undertook the publication of the magazine *Palestine* and generally sought to win British leaders to an acceptance of the desirability of "an alliance between Zionism and Great Britain." [12]

The years 1914–16 were spent by the Zionist leaders in propaganda and in informal conversations with British leaders.[13] Dr. Weizmann had interviews with Lloyd George, Herbert Samuel, and Arthur Balfour, all of whom expressed interest in the Zionist program.[14] Sir Mark Sykes, who had negotiated for Great Britain the secret treaty with France on the Near East,[15] had become convinced, as had the Manchester group, that the Zionist policy for Palestine could be made to coincide with British interests in the Mediterranean area. In the government formed by Lloyd George in December, 1916,

[9] See Herbert Sidebotham, *Great Britain and Palestine* (London: The Macmillan Co., 1937), pp. 28–50. [10] *Ibid.*, pp. 38–40.

[11] *Zionist Executive Reports*, XII (1921), *Political Report*, p. 9.

[12] Sidebotham, *op. cit.*, p. 43. For a more complete description of the British Palestine Committee see Sokolow, *op. cit.*, II, 424–425.

[13] *Zionist Executive Reports*, XII (1921), *Political Report*, pp. 8–9. See also Dugdale, *Arthur James Balfour*, II, 222–228.

[14] Dugdale, *The Balfour Declaration*, pp. 22–23. On Dr. Weizmann's contacts with high British officials see also David Lloyd George, *Memoirs of the Peace Conference* (New Haven: Yale University Press, 1939), II, 722–723.

[15] The Sykes-Picot Agreement of May, 1916. For the rôle played by Sir Mark Sykes in the negotiations leading to the Balfour Declaration see Dugdale, *The Balfour Declaration*, pp. 25–26.

Balfour was secretary of state for foreign affairs. Both Lloyd George and Balfour were sympathetic to Zionist aims. Other members of the Lloyd George cabinet friendly to the Zionist proposals for Palestine included Lord Milner, General Smuts, and Lord Cecil.[16] Thus it was that by 1917 Zionism had won many supporters in influential British governmental circles.[17]

The more formal negotiations between the Zionists and the British Government began early in 1917. The first meeting took place on February 7, at the house of Dr. Moses Gaster. Present at this meeting in addition to Dr. Gaster were Sir Mark Sykes, Lord Rothschild, Mr. Harry Sacher, the Right Honorable Herbert Samuel, Mr. Herbert Bentwich, Mr. Joseph Cowen, Mr. James de Rothschild, Dr. Chaim Weizmann, and Dr. Nahum Sokolow. Sir Mark Sykes was by now the accredited representative of the British Government and Dr. Weizmann and Dr. Sokolow were the designated representatives of the Zionist organization. As the talks continued, their substance was communicated to the French and Italian Governments and to the Zionist organizations in the United States and Russia. In March of 1917 Dr. Sokolow went to Paris, where he explained the Zionist program to French leaders and received the assurances of the French Government that the program was viewed with favor.[18] Similar expressions were received from Pope Benedict XV and from the Italian foreign minister.

Meanwhile, despite the evident progress of the Zionist plans, all was not unity within the ranks of the Jews. In fact, opposition to the Zionist policy for Palestine came to a surprising extent from the Jews themselves. In Jewish circles there had been a long-standing disagreement between the "spiritual Zionists," who wanted Palestine to serve as a center of Jewish culture and little more, and the "political Zionists," who sought to transform Palestine into an independent Jewish state.[19] When it became evident that any

[16] Lloyd George, *op. cit.*, II, 723.

[17] As early as March, 1915, Dr. Weizmann wrote to Mr. C. P. Scott: "The British Cabinet is not only sympathetic towards the Palestinian aspirations of the Jews, but would like to see them realised." Quoted in Dugdale, *The Balfour Declaration*, p. 24.

[18] See the letter of June 4, 1917, from Jules Cambon to Dr. Sokolow. Reproduced in Sokolow, *op. cit.*, II, 53.

[19] For a statement of the arguments against political Zionism see Morris Jastrow, *Zionism and the Future of Palestine: The Fallacies and Dangers of Political Zionism* (New York: The Macmillan Co., 1919), 159 pp.

British declaration on Palestine would strongly favor political Zionism, the other group began to voice manifest disapproval.

The Jews who opposed the Zionist program were headed in Britain by the influential Conjoint Committee, described as "the most influential of all Jewish bodies in England."[20] The Conjoint Committee was originally established to seek the intervention of the British Government in cases of flagrant persecution of Jews, wherever throughout the world these persecutions might occur. The Committee was composed of eminent English Jews, and its relations with the British Government were "always highly satisfactory."[21]

Already on October 1, 1916, the Conjoint Committee had submitted a memorandum on Palestine to the British Government. The implications of this document clearly precluded a Jewish commonwealth in Palestine and showed the fundamental divergence of opinion between the Conjoint Committee and the Zionists.[22] "The Conjoint Committee," as the Zionist executive later stated, "pinned its faith to civil and political emancipation. . . . It was irrevocably opposed to Jewish nationalism."[23]

As the Zionists continued their negotiations with the British Government during the first months of 1917 and a successful outcome seemed likely, the Conjoint Committee determined to take a further and more drastic action in the attempt to forestall a declaration supporting the Zionist program. The early representations of the Jewish opponents of the proposed declaration had been for the most part of a private nature. On May 24, 1917, however, there appeared over the signatures of David L. Alexander, president of the Board of Deputies of British Jews, and Claude G. Montefiore, president of the Anglo-Jewish Association, a letter in the *London Times* flatly condemning the Zionist policy.[24] There were two principal arguments in the letter. First of all it was contended that if the Jewish settlements in Palestine were to be "recognized as possessing a national character in a political sense," this "establishment of a Jewish nationality in Palestine . . . must have the effect throughout

[20] Ziff, William B., *The Rape of Palestine* (New York: Longmans, Green and Co., 1938), p. 57.

[21] *Zionism*, in *Peace Handbooks* (Vol. X), No. 162, p. 38.

[22] The salient parts of the memorandum appear in *Zionist Executive Reports*, XII (1921), *Political Report*, p. 8; and Sidebotham, *op. cit.*, pp. 56–57.

[23] *Zionist Executive Reports*, XII (1921), *Political Report*, p. 8.

[24] The text of the letter is also reprinted in Sokolow, *op. cit.*, II, 58–61; and in *Zionism*, in *Peace Handbooks* (Vol. X), No. 162, pp. 39–42.

the world of stamping the Jews as strangers in their native lands and of undermining their hard-won positions as citizens and nationals of those lands." Here the British Jews, protected by citizenship in a state that was at once powerful and not particularly hostile to Jews, revealed their fear that the creation of a Jewish commonwealth in Palestine would deprive them of their British citizenship and leave them dependent for their protection on a state that would be new, small, and perhaps quite unable to assure the protection that British citizenship guaranteed. The second argument was that any proposal to invest the Jews in Palestine with special rights in addition to those enjoyed by the rest of the population might involve the Jews in "the bitterest feuds with their neighbors of other races and religions. . . ." This public declaration raised a storm of protest from the Zionists, and the correspondence columns of the *Times* were flooded with letters designed to refute the Conjoint Committee's allegations.

In spite of its vigorous attack on the Zionist program, the Conjoint Committee was unable to prevent a British declaration favorable to Zionism. The men who were responsible for forming British governmental policy in 1917 had been won to the viewpoint of the Manchester group. The Conjoint Committee, of whom it had been reported that "the Foreign Office never turned a deaf ear to its representations,"[25] was in this instance overruled.

Yet it must be emphasized that the decisive influence in the issuing of the Balfour Declaration and in the sponsoring of the policy which the Declaration indicated was British and not Jewish. The Declaration is testimony to the fact that the majority of influential British officials, in line with the Manchester group, had come to believe that there was an identity of interests between Zionism and British policy in the Middle East. Had this not been so, all Zionist propaganda would have gone for nought. Britain accepted the Zionist policy rather than the representations of the Conjoint Committee, not primarily because of a moral or ideological preference for Zionism, but because Zionism, so it was believed, best answered British needs. "It was in fact," Mr. Sidebotham records, "the needs, political and strategic, of British policy, that definitely inclined the scale in favour of Zionism."[26]

[25] *Zionism*, in *Peace Handbooks* (Vol. X), No. 162, p. 38.
[26] *Op. cit.*, p. 55.

Thus, although "altruistic motives, stimulated by deep feelings on the subject of the Holy Land, contributed to the British Government's decision . . .,"[27] the policy of the Balfour Declaration was naturally intended to serve British interests. "It would be wrong," said the Zionist executive in its *Political Report* to the 1921 Zionist Congress, "to represent the Declaration as a piece of pure political idealism."[28]

The value to Great Britain of the Balfour Declaration has been pointed out by many observers, among whom George Antonius gives a most interesting description:

> . . . Mr. Lloyd George appointed Sir Mark Sykes to open negotiations with the Zionists. What his motives were in wishing to come to an understanding with the Zionist leaders, and what the considerations were which induced the British Government eventually to issue the Balfour Declaration are questions to which the answers have been obscured by a smoke-screen of legend and propaganda. It is alleged, for instance, that the Jews used their financial and political influence to bring the United States into the War on the side of the Entente and that the Balfour Declaration was a reward for actual services rendered. All the published evidence goes to disprove that allegation, and one can only infer either that it does not rest on any foundation or, if it does, that the services rendered by international Jewry in that connexion were of so occult a nature that they have hitherto escaped the scrutiny of all the historians of America's intervention. Again, it is often stated that the Balfour Declaration was issued in return for promises pledging large subscriptions from Jewish sources to war-loan funds; but that, too, may safely be discounted. The available evidence is too fragmentary to be of value and, so far as it goes, tends to show that the most substantial purchases of British war-loan stock that can be traced to Jewish sources in 1917 and 1918 were made in the name of Jews who were opposed to the policy foreshadowed in the Balfour Declaration. Yet another legend is that which attributes the genesis of the Declaration to a desire on the part of the British Government to reward Dr. Weizmann for his timely invention of a new explosive.
>
> In actual fact, the British Government were moved mainly by two considerations. One was political: to win over the powerful Zionist elements in Germany and Austria, who were actually in negotiation with the Central Powers for the issue of a Turkish "Balfour Declaration," by providing them with a positive interest in an Entente victory; and, at the same time, to mitigate the hostility of Jews in Allied countries towards Russia and give those Jews, who had been so active in overthrowing the Tsarist régime, an incentive to keep Russia in the War. The other was the imperialistic motive, first propounded by Kitchener, of securing Palestine or a portion of it as a bulwark to the British position in Egypt and an overland link with the East. This motive was the dominant one and whatever part other considerations — financial, political, religious or hu-

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[27] *Great Britain and Palestine 1915–1939*, The Royal Institute of International Affairs, Information Department Papers No. 20A (London: Oxford University Press, 1939), p. 9.

[28] *Zionist Executive Reports*, XII (1921), *Political Report*, p. 13.

manitarian — may have played, there is no doubt that it sufficed by itself to bring about the Balfour Declaration. And it may legitimately be assumed that had they not come to an agreement with the Zionists, the British Government would have tried every means open to them of concluding such other bargains as would have ensured the reversion of Palestine to Great Britain as her share of the spoils of war.[29]

British leaders have freely admitted that the Declaration was intended to serve British interests. Lloyd George, who was prime minister in 1917, declared subsequently: "It was important for us to seek every legitimate help we could get. We came to the conclusion from information we received from every part of the world that it was vital we should have the sympathies of the Jewish community."[30] In testimony before the Peel Commission Lloyd George, after reviewing the serious position in which Britain and the Allies found themselves at the close of 1916, stated similarly: "In this critical situation it was believed that Jewish sympathy or the reverse would make a substantial difference one way or the other to the Allied cause."[31] Finally, although the examples might be multiplied, Winston Churchill said in the House of Commons on July 21, 1937:

> It is a delusion to suppose that this [the issuing of the Balfour Declaration] was a mere act of crusading enthusiasm or quixotic philanthropy. On the contrary, it was a measure taken . . . in the dire need of the War with the object of promoting the general victory of the Allies, for which we expected and received valuable and important assistance.[32]

These statements suggest that there were three main considerations of value to Britain and the Allies in the program of the Balfour Declaration. These constitute the *Realpolitik* of the British Palestine policy:

1. The view strongly urged by the Manchester group and already

[29] *The Arab Awakening: The Story of the Arab National Movement* (London: Hamish Hamilton, Ltd., 1938), pp. 260–261. See also H. W. V. Temperley (ed.), *A History of the Peace Conference of Paris* (London: Frowde, Hodder and Stoughton, 1920–24), VI, 171–174; John de Vere Loder, *The Truth about Mesopotamia, Palestine and Syria* (London: George Allen and Unwin, 1923), pp. 149–150; Sidebotham, *op. cit.*, pp. 55–56; *Peel Report*, p. 23; *Great Britain and Palestine 1915–1939*, pp. 9–10; and David H. Popper, *The Puzzle of Palestine* (New York: Foreign Policy Association, 1938), p. 30.

[30] *Parliamentary Debates, House of Commons*, June 12, 1936, Vol. 313, col. 1343. See also Lloyd George, *op. cit.*, II, 723, 724–726, 737.

[31] *Peel Report*, p. 23.

[32] *Parliamentary Debates, House of Commons*, Vol. 326, col. 2330.

touched upon that "there was the chance of introducing a Jewish element into Palestine, bound by ties of gratitude to Great Britain, which would turn Palestine into an advanced bastion for the defence of the Suez Canal." [33]

2. The desire to gain the support of Jews throughout the world and of American and Russian Jews in particular.

3. The desire to forestall the Central Powers, who seemed ready to make a similar promise to the Jews.[34]

These were the not wholly disinterested motives that led Great Britain to sponsor the Balfour Declaration.

The British Government, having come to the conclusion that the establishment of a Jewish Palestine — connected in some way with the British Empire — was in the interest of Britain, was not disposed to allow disunity within Jewish circles to block the promotion of such a program. Therefore the objections of the anti-Zionists were dealt with by the Government. These objections were partly overruled and partly met with compromise. The national-home idea in the Declaration did give a special position to the Jews in Palestine and thus failed to heed the second objection in the Conjoint Committee's anti-Zionist letter of May 24, 1917. However, in the hope of securing comparative unanimity among the Jews, the British Government placated the Conjoint Committee to the extent of inserting a proviso in the Declaration to the effect that the rights and political status enjoyed by Jews in any other country would not be prejudiced.

The Lloyd George cabinet itself was strongly divided on the question of the sort of pro-Zionist declaration that should be made.[35] The details of the cabinet discussions have not been made public and "will only be certainly known when some day the Cabinet archives are laid open." [36] Enough is known, however, to indicate that the cabinet contained the same opposing viewpoints as did English

[33] Loder, *op. cit.*, pp. 149–150.

[34] Lloyd George (*op. cit.*, II, 725–726) has suggested that this was a very real factor: ". . . The German General Staff . . . urged, early in 1916, the advantages of promising Jewish restoration to Palestine under an arrangement to be made between Zionists and Turkey, backed by a German guarantee. . . . At any moment the Allies might have been forestalled in offering this supreme bid. In fact in September, 1917, the German Government were making very serious efforts to capture the Zionist Movement."

[35] See *Peel Report*, p. 24; and *Zionist Executive Reports*, XII (1921), *Political Report*, pp. 12 ff.

[36] Dugdale, *The Balfour Declaration*, p. 29.

Jewry. The chief cabinet opponent of a declaration favoring a national home for the Jews in Palestine was Mr. Edwin Montagu, the secretary of state for India.[37] Mr. Montagu was himself a Jew, but thoroughly an Englishman, and strongly antagonistic to anything which might undermine his rights as a British subject. Lloyd George has written this description of Mr. Montagu:

> He belonged to a small and dwindling minority of Jews — mostly wealthy — who had no desire that Israel should be regarded as a separate race and a distinct nationality. Such of them as still professed their adhesion to Judah regarded it as a definite religion and not as a peculiar people. Mr. Montagu had not even these religious predilections. As he himself once mournfully said to the late Lord Morley, "I have been striving all my life to escape from the Ghetto." He was therefore a convinced and a bitter anti-Zionist.[38]

In addition to Mr. Montagu, Lord Curzon was at first against the Declaration — largely because he doubted that Palestine could be agriculturally or industrially developed so as to maintain any substantial increase in population.[39] He withdrew his objection to the Declaration, however, before the final vote of the war cabinet.[40]

Notwithstanding Mr. Montagu's violent opposition and Lord Curzon's initial disapproval, the Zionists had strong support in the cabinet. Prime Minister Lloyd George, Foreign Secretary Balfour, Lord Milner (secretary of state for the colonies), and Lord Robert Cecil (minister of blockade) were in sympathy with the Zionist program and alive to the advantages that the proposed Declaration offered to Britain.

The Zionists and the British Government had begun serious discussions on the question of a British statement favoring Zionism in February, 1917. By summer Balfour himself was taking an active rôle.[41] In July a preliminary draft of the declaration was prepared. This July draft was accepted by Sir Mark Sykes, Lord Rothschild, and also President Wilson. It was forwarded to Balfour himself on July 18, 1917. It read:

[37] Mr. Montagu is described as "the very spear-head of Anglo-Jewish opposition to the Zionist movement." Dugdale, *Arthur James Balfour*, II, 214. Sir Ronald Storrs refers to the "ultra-Islamic" character of the India Office. *The Memoirs of Sir Ronald Storrs* (New York: G. P. Putnam's Sons, 1937), p. 362.

[38] *Op. cit.*, II, 732–733.

[39] See Lord Curzon's memorandum for the cabinet dated October 26, 1917, on "The Future of Palestine," *ibid.*, pp. 727–732.

[40] *Ibid.*, p. 735.

[41] *Ibid.*, p. 723.

H. M. Government, after considering the aims of the Zionist Organisation, accepts the principle of recognising Palestine as the National Home of the Jewish people, and the right of the Jewish people to build up its National Life in Palestine under a protection to be established at the conclusion of Peace, following upon the successful issue of the war.

H. M. Government regards as essential for the realisation of this principle the grant of internal autonomy to Palestine, freedom of immigration for Jews, and the establishment of a Jewish National Colonising Corporation for the resettlement and economic development of the country.

The conditions and forms of the internal autonomy and a charter for the Jewish National Colonising Corporation should in the view of H. M. Government be elaborated in detail and determined with the representatives of the Zionist Organisation.[42]

This July draft of the declaration also received Balfour's approval. The matter was then placed before the cabinet in August, 1917. There the draft declaration struck a serious snag. "Rumours of opposition in the Cabinet became certainties." [43]

It was the secretary of state for India, Mr. Montagu, who led the offensive against the proposed declaration. Late in August he submitted to the cabinet a document which Lord Balfour's niece, Mrs. Dugdale, refers to as a "memorandum of passionate protest" against the July draft of the declaration.[44] Mr. Montagu argued, as had the Conjoint Committee, that to use the phrase "Jewish National Home" in connection with Palestine would "vitally prejudice the position of every Jew elsewhere." "How would he [Mr. Montagu] negotiate with the peoples of India on behalf of His Majesty's Government if the world had just been told that His Majesty's Government regarded his national home as being in Turkish territory?" [45] The cabinet was "more than shaken" by Mr. Montagu's attack, and as late as September 24 Balfour was speaking of the necessity of reversing a decision that had been taken by the cabinet *against* the Zionists.[46]

From late August until early November of 1917 the controversy over the proposed pro-Zionist declaration raged intermittently in both the cabinet and the war cabinet. During this period significant alterations were made in the verbal text of the July draft of the

[42] Quoted in *Zionist Executive Reports*, XII (1921), *Political Report*, pp. 71–72; Sidebotham, *op. cit.*, pp. 58–59; and J. M. N. Jeffries, *Palestine: The Reality* (London: Longmans, Green and Co., 1939), pp. 163–164.

[43] Dugdale, *Arthur James Balfour*, II, 215.

[44] *Ibid.*, p. 233.

[45] See Mr. Montagu's statement in Lloyd George, *op. cit.*, II, 733.

[46] Dugdale, *Arthur James Balfour*, II, 233.

declaration, as a comparison of that draft with the final form readily shows. These changes in the phraseology were deliberate, and hence they shed a great deal of light on what the Balfour Declaration actually promised the Jews and what it did not promise them. These matters cannot be discussed here except for this very suggestive point: The July draft promised the Jews recognition by the British Government of Palestine as *the* Jewish national home, but the final Declaration promised British support only for *a* Jewish national home *in* Palestine — which is certainly quite a different commitment and a less far-reaching one.

As diplomatic and military considerations indicated more and more strongly the necessity of some official expression of British sympathy with Zionist aspirations, even Mr. Montagu ultimately came to accept the Declaration as desirable from the standpoint of military expediency.[47] Accordingly, when the Declaration, in the textual form which resulted from the long and controversial interchange of views, came up for the final decision of the war cabinet there existed little question as to the outcome. Lord Balfour spoke in support of it. He emphasized the political value to the Allies of a pro-Zionist declaration and stressed especially the propaganda value of such a declaration in both Russia and the United States.[48] Lord Curzon then spoke briefly. Beyond this the trend of the discussion is not known; but the Declaration was of course approved.

On November 2, 1917, the Balfour Declaration was issued. In form it was a letter from the secretary of state for foreign affairs, Arthur J. Balfour, to Lord Rothschild. The text of the letter follows:

Foreign Office,
November 2nd, 1917

Dear Lord Rothschild,

I have much pleasure in conveying to you, on behalf of His Majesty's Government, the following declaration of sympathy with Jewish Zionist aspirations which has been submitted to, and approved by, the Cabinet.

"His Majesty's Government view with favour the establishment in Palestine of a national home for the Jewish people, and will use their best endeavours to facilitate the achievement of this object, it being clearly understood that nothing shall be done which may prejudice the civil and religious rights of existing non-Jewish communities in Palestine, or the rights and political status enjoyed by Jews in any other country."

[47] Lloyd George, *op. cit.*, II, 733.
[48] *Ibid.*, p. 735.

I should be grateful if you would bring this declaration to the knowledge of the Zionist Federation.

Yours sincerely,
[signed] Arthur James Balfour [49]

The other Allied and Associated Powers had been kept informed of the progress of the negotiations between the Zionists and the British Government. The French and Italian Governments had expressed to Dr. Sokolow their sympathy with Zionist aims, and, following the publication of the Declaration, these Powers and a number of other states publicly endorsed it.[50] France officially approved the Balfour Declaration on February 14, 1918.[51] The Italian endorsement followed on May 9, 1918.[52] Japan voiced official approval in January of 1919.[53] Finally, the United States Government, although not at war with Turkey, displayed its immediate approval of the Declaration through public statements by President Wilson;[54] and in 1922 the Sixty-seventh Congress adopted a joint resolution approving the Balfour Declaration.[55]

In addition to these endorsements the Balfour Declaration was incorporated in the Treaty of Sèvres and in the text of the mandate

[49] Text taken from the facsimile reproduction of the Balfour Declaration in Dugdale, *The Balfour Declaration*, p. 4. The full text of the letter is also printed in Sokolow, *op. cit.*, II, 83; Andrews, *op. cit.*, I, 334–335; and *Zionist Executive Reports*, XII (1921), *Political Report*, p. 72.

[50] The Zionist memorandum to the Peace Conference, February 3, 1919, listed the following states as having approved the Balfour Declaration: France, Italy, the United States, Japan, Greece, Serbia, China, and Siam. David Hunter Miller, *My Diary at the Conference of Paris* (New York: Printed for the author by the Appeal Printing Co., 1924), V, 20–21. See also the list of endorsements in Herbert Sidebotham, *British Imperial Interests in Palestine* (London: British Palestine Committee, 1936), pp. 28–29.

[51] The French endorsement was in the form of a press communiqué, a copy of which was officially sent to Dr. Sokolow. See the text in Sokolow, *op. cit.*, II, 128; and *Zionist Executive Reports*, XII (1921), *Political Report*, p. 72.

[52] The Italian endorsement was a note from the Italian ambassador in London to Dr. Sokolow. See the text in Sokolow, *op. cit.*, II, 129; and *Zionist Executive Reports*, XII (1921), *Political Report*, p. 73.

[53] Andrews, *op. cit.*, I, 342.

[54] The Report of the House Committee on Foreign Affairs on H. J. Res. 322 (67th Cong., 2d Sess.) favoring the establishment in Palestine of a national home for the Jewish people quotes from letters by both President Wilson and President Harding expressing agreement with the policy of the Balfour Declaration. *Congressional Record*, 67th Cong., 2d Sess., June 30, 1922, Vol. 62, pp. 9799–9800. See also the letter by President Wilson quoted in Sokolow, *op. cit.*, II, 130–131.

[55] The joint resolution was approved September 21, 1922. Public Resolution No. 73, 42 Stat. 1012.

for Palestine. The inclusion of the Declaration in the mandate and the approval of the mandate by the League Council on July 22, 1922, signified perhaps the tacit approval of the members of the League, and certainly the specific approval of the states at that time occupying seats on the Council.[66] Thus the policy of the Balfour Declaration received indications of support by many states throughout the world.

Nevertheless, the British Government remained chiefly responsible both for the origin and the execution of the promise to support a Jewish national home in Palestine. That Government had entered into negotiations with the Zionist organization and had issued the original Balfour Declaration. Also, Britain became responsible for implementing the Declaration when the mandates system was established at the conclusion of the first World War. It was named Mandatory Power for Palestine, and the Balfour Declaration with its promise of British support for a Jewish national home in Palestine was written verbatim into the terms of the mandate.

From this study of the origins of the Balfour Declaration the following three conclusions may be suggested by way of summary:

1. The objects of the British Government in sponsoring the Balfour Declaration were not wholly disinterested. The Declaration was partly a measure of war propaganda and partly an "insurance policy" designed to secure British imperial interests in the Mediterranean area under the peace settlement which would follow the war. In part, however, the Declaration was undoubtedly an expression of actual British interest in Zionism.
2. The chief opposition to a pro-Zionist declaration by the British Government came from the Jews themselves.
3. A comparison of the July draft of the declaration with the final Declaration aids greatly in interpretation. Here the point of most importance is that the Balfour Declaration in its final form promised the Jews not Palestine as *the* Jewish national home, but *a* Jewish national home *in* Palestine.

Thus the Balfour Declaration was formulated — a single sentence of but sixty-seven words, imprecise and in part ambiguous, yet indi-

[66] See paragraph 8 of Article 22 of the League of Nations Covenant. States having seats on the Council in 1922 were Great Britain, France, Italy, Japan, Spain, China, Brazil, and Belgium.

cating some measure of British support for the age-old Zionist dream of a return of the Jews to Palestine. From the Balfour Declaration and the questions of policy arising out of it have come since the first World War an unending series of British–Arab–Jewish disputes over Palestine — disputes always serious, often intensely bitter, and on occasion violent. And the end, it may be safely asserted, is not yet.

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THE NANSON SYSTEM: A MICHIGAN EXPERIMENT IN VOTING

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THE American system of representative government is posited upon the hypothesis of majority rule. Yet under the traditional method of voting departures from majority rule are common, and are especially evident in party primaries and in general elections when more than two candidates are competing. The critics of the system insist that this weakness in representative government can be overcome only by providing the voter with a method of registering a judgment on all candidates, each against a single rival.[1] Such a method can be provided in either of two ways: (1) by holding a series of "two-by-two" elimination elections, or (2) by the use of an election system in which the voter, in the marking of a single ballot, indicates his choice among all the candidates on a two-by-two basis. The first of these methods is too long and too complicated to be urged as a practical solution to the problem, but the result can be approximated by the adoption and use of the other method, the preferential ballot.

The proponents of preferential voting have been the severest critics of the conventional plurality system. They contend that any one of the several plans of preferential voting is superior to the conventional method, and will, wherever multiple candidates are concerned, approximate majority selections. A further advantage claimed for these systems is that they combine the nomination with the election, thereby eliminating the necessity for the primary election. The filing of a nominating petition insures the candidate of a place on the ballot. Of the many types of preferential voting,

[1] "There exists but one rigorous method of ascertaining the wish of a majority in an election. It consists in taking a vote on the respective merits of all the candidates compared two by two." Condorcet's test; see *Œuvres complètes de Condorcet*, ed. by D. J. Garat and P. J. G. Cabanis (21 vols.; Brunswick: Vieweg; Paris: Heinrichs, 1804), XV, 28–29. Quoted by Hoag, C. G., "Effective Voting," Senate Document No. 359, 63d Cong., 2d Sess. (Doc. No. 6593), p. 9.

the Ware and the Bucklin systems are best known in the United States.[2] The Nanson method, described as superior to the other types, is little known in this country and has been put to actual use only in Marquette, Michigan.[3]

This system has been briefly described by Hoag:

> . . . A majority preferential system that differs from the Ware and the Bucklin essentially only in the rules of the count was devised by Prof. E. J. Nanson of the University of Melbourne, Australia, and described by him in a paper read before the Royal Society of Victoria in 1882 and reprinted in the Blue Book of the British Government designated "Miscellaneous No. 3, 1907." Under this system a first choice is given more credit than a second throughout the entire count, a second more than a third, and so forth. Then, in accordance with simple rules formulated by Prof. Nanson on the basis of a complete mathematical solution of the problem, those candidates whose total credits show them to be unquestionably inferior to other candidates in the opinion of the voters as indicated on the ballots are successively dropped out as defeated until the candidate preferred to any other is left and declared elected.[4]

Preferential voting systems differ from the conventional method both in the type of ballot and in the method of the count. In preferential voting the voter marks his ballot by placing the numerals 1, 2, 3, and so on opposite the names of the candidates in such a manner as to indicate his first choice and, thereafter, the order of his choices.[5] The preferential systems differ from one another principally in the method of the count. In each of the plans the counting begins by determining the number of *first* choices registered for each candidate. If any candidate secures a clear majority of such choices he is declared elected; however, if no candidate secures a majority the plans proceed, but by different methods, to determine a "majority opinion" by assigning values to the succeeding choices until a candidate has been elected. Under the Ware plan the candidate who received the fewest "firsts" is dropped from the list after the first

[2] See Robert C. Brooks, *Political Parties and Electoral Problems* (3d ed.; New York: Harper and Bros., 1917), pp. 482–484.

[3] The charter of Wakefield, Michigan, was amended to authorize the city commission to adopt a preferential ballot system, and a plan similar to the one in Marquette was drafted. The commission was advised that the plan would be unconstitutional if put into effect, and, consequently, no further action was taken.

[4] Hoag, *op. cit.*, p. 8.

[5] There are some variations in ballot forms. One form carries at either the right or the left of the list of candidates a number of columns equal to the number of choices permitted. The voter marks his ballot by placing crosses in the appropriately numbered columns, thereby indicating the order of his choices.

enumeration, and his votes are distributed among the remaining candidates as ordered by the second choices. This procedure is repeated until a candidate is elected or until all but one of the candidates have been eliminated. The candidate surviving the elimination is declared elected. Under the Bucklin plan no candidates are dropped from the list. If none secures a majority of first choices, the second choices are added to obtain new totals, and the procedure is continued, i.e. third, fourth, and later choices are added until a candidate receives a majority of all the votes. If the votes are exhausted before a candidate secures a majority, the person with the largest total is declared elected.

The Nanson plan comes closer than either the Ware or the Bucklin system to meeting the requirement of Condorcet's test, i.e. of matching all candidates two by two. "Fortunately the Nanson count can give nothing but such a correct result in any case, for it is simply a convenient formulation of a mathematical principle that covers all cases." [6] Further, it is the one system which in all instances accords a proper and fair value to each expressed choice:

> Under the Nanson rules no candidate is dropped out until it is mathematically certain that he is not the strongest according to Condorcet's test; and *a lower choice is not reckoned as equal to a higher choice in any contingency;* from first to last *the gradations of each voter's preferences are preserved and given effect in the count.*[7]

Although the counting procedure under this plan is complicated, the rules have been briefly summarized by Hoag:

> 1. At the voting precincts transcribe on coordinate paper (ruled to correspond with the spacing of the names of the candidates on the ballot) the figures marked on the ballots by the voters, using a separate column for each ballot and numbering both ballot and column with a distinctive number in order to be able at any time to compare the original ballot with its record. Send the record to the central electoral board, as ordered by that board.
>
> 2. On the record, but not on the ballots, let the central electoral board fill in all blank spaces with a figure found by dividing by two the sum of the number of candidates and a number one higher than that indicating the last preference marked on the ballot by the voter. [This is merely finishing the voter's work by giving each unmarked candidate the average to which all unmarked candidates are entitled. It insures the counting of the ballot in the subsequent addition to the disadvantage, and to the equal disadvantage, of the unmarked candidates, just as the voter intended. Example: If there were seven candidates, the blank spaces on ballots showing only three preferences would all be filled in with the number $5\frac{1}{2}$; those on ballots showing four preferences, with the number 6, and so on.]

[6] Hoag, *op. cit.*, p. 14. [7] *Ibid.*, p. 12.

3. Add the figures of each candidate.

4. Exclude as defeated every candidate whose total is equal to or more than the average. [This is reasonable because the voter used larger figures to represent lower preferences.]

5. If more than two candidates remain, set down on record sheets figures representing the preferences on all the ballots as among the candidates remaining. Add again, and again eliminate all candidates whose total is equal to or more than the average.

6. Proceed again, if necessary, as prescribed in rule 5, until only two candidates remain. When only two remain, examine the record to see which of those two was preferred to the other by the voters, and declare him elected.

7. If only one candidate remains after an elimination of candidates, declare him elected.[8]

The proponents of preferential voting admit that because of peculiar characteristics each of the plans invites some type of vote manipulation. The Ware count, with its series of eliminations, encourages the voter who believes that his favorite candidate cannot poll enough "firsts" to escape immediate defeat to support less acceptable but relatively stronger candidates. Under the Bucklin plan all choices are given equal weight in the determination of successive totals, and if a candidate is not elected on the first count the second-choice vote may be regarded as a vote against the first-choice candidate. When this system is used the voter may hesitate to express any choice after the first. If the practice of voting a single choice is widespread, the election yields, in spite of the ballot form, a simple plurality winner.

The Nanson count, with its system of weighted choices, presents a different type of problem. It permits the voter to fortify further the position of his favorite candidate by manipulating his subsequent votes to the detriment of the leading rival. If the comparative strength of the rival candidates can be accurately predicted, the voter can secure an additional advantage for his favorite by voting his last choice for the strongest rival. This practice when widely used, would, in exceptional situations, result in the accumulation of sufficient second- and third-choice strength to elect relatively weak and undesirable candidates. In noting this characteristic of the system, Hoag expressed the opinion that it would not constitute a major weakness.[9] In spite of his optimism, this was one of the factors which contributed to the collapse of the experiment in Marquette.

[8] Hoag, *op. cit.*, pp. 8–9. The bracketed matter is Hoag's comment.

[9] "It amounts simply to this, that a voter who feels sure that he can predict which candidate will prove to be his favorite's strongest rival has the privilege

Popular demands for the introduction of revised voting methods reached their height in the reform movement of the first two decades of the twentieth century. During that period many American cities, including several in Michigan, experimented with proportional representation and preferential voting. Prompted in part by the reform spirit and in part by genuine dissatisfaction with existing election machinery, the voters of Marquette amended the city charter, authorizing the commission to adopt by ordinance "a majority preferential ballot system of voting for officers of said city . . . ."[10] An ordinance incorporating the essential features of the Nanson system was adopted by the commission on August 26, 1918.[11] The system was used for the first time in the municipal elections in December of that year.

The proposal stimulated little interest, and a relatively light vote was registered on the issue. No substantial opposition developed prior to the election of April 2, 1917, and only 87 votes out of a total of 283 were cast against the proposal. In the course of its deliberations the commission announced an open hearing on the ordinance. Only one person appeared, and he urged its adoption. On August 20, 1918, the *Mining Journal* discussed in a news item the merits of the proposal and concluded that if adopted the system would insure majority selections and would save the taxpayers from two to three hundred dollars each year, the cost of the primary election. Two days later the same paper reviewed the merits of the Nanson system and said that its adoption would eliminate "political

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of taking the risk of injuring the chances of that supposed rival, against others still less desirable, in order to avoid helping that rival's chances against the candidate of the voter's first choice to the extent that he would by marking the rival as second choice under rules providing that under no circumstances can a second choice count *equally* with a first. And I see no grave objection to a voter's having this privilege." Hoag, *op. cit.*, p. 13.

[10] "The Commission is hereby empowered, from time to time, to establish, alter or abolish, by ordinance not adopted as an emergency measure, a majority preferential ballot system of voting for officers of said city . . . ." *Amendment, Charter of Marquette*, chap. 6, sec. 7. Adopted April 2, 1917.

[11] The ordinance was drafted by George P. Brown, city attorney. Mr. Brown had made a rather careful study of preferential voting and was apparently its leading advocate in Marquette. He studied also American court decisions dealing with proportional representation and preferential voting and prepared an elaborate brief in anticipation of a test of the legality or constitutionality of the Nanson system. The system was not, however, attacked in the courts. A copy of Mr. Brown's brief is on file in the office of the city clerk, Marquette, Michigan.

jockeying" to split the opposition and would insure an election in which all the candidates would be matched two by two.[12]

Although used in the elections of 1918 and 1919 the system was put to its first real test in 1920. Some criticism of it developed in a three-cornered contest for the office of supervisor.[13] This criticism was relatively mild and was directed primarily against the form of the ballot rather than against the method. The fact that the ballot provided a space rather than the familiar box confused the voters, and at least one hundred ballots were thrown out in spite of the fact that the election officials counted all improperly marked ballots from which they were able to ascertain a clear intention. In one ward, however, the charge was made that the voters did not understand the system. Fortunately the contest was not close, and voters and candidates alike accepted the results of the count without question. The local press defended the method, but severely criticized city officials for the form of the ballot and the inadequacy of the voting instructions.[14]

In the next seven years (1921–27), there were no contests, and, consequently, the system attracted little or no attention. But in 1928 the storm of criticism and protest arising out of a three-cornered campaign featured by a political feud between two outstanding candidates demonstrated that it could not survive in the absence of positive support. Although one of the prominent candidates won, the third and supposedly weaker and less qualified candidate scored scarcely more points under the Nanson count than were recorded for the second leading candidate. The election results suggested the presence of the peculiar type of vote manipulation encouraged by the Nanson plan. There is no written record and no substantial evidence

[12] *The Mining Journal*, August 22, 1918. There are reasons to believe that these two news items were inspired by Mr. Brown (see note 11, p. 617).

[13] There can be no test of the merits of preferential voting unless three or more candidates are competing for the same office. When there are only two candidates the election is decided by first choices and in those cases the conventional ballot is equally satisfactory. In 1918, in 1919, and in several subsequent elections there were not more than two candidates for each office. For the purposes of this discussion it will be assumed that there were no contests unless three or more candidates were entered.

[14] The tangible evidence may not demonstrate the seriousness of the criticism. Mr. Brown (see note 11, p. 617) either prepared or revised his brief in anticipation of a court challenge sometime between 1920 and 1923. Since the election of 1920 provided the only contest in the years 1918–25, it is reasonable to conclude that the threats of legal action grew out of the election of 1920.

to support the charge, but it appears to have been widely believed that there had been a silent understanding, if not actual collusion, between the first- and last-place candidates. It was believed that the followers of each were instructed to exchange second-place support, thus insuring an accumulation of third choices sufficient to defeat the second candidate. Even though the charges of manipulation cannot be substantiated, protests against the continued use of the system were unmistakable.

The *Mining Journal*, which had for ten years supported the plan, began an attack to insure that this would be the last election in which the preferential ballot was used. The results of the municipal election were determined, said the paper, "after a tired, goggle-eyed counting board of seven or eight persons, including at least one expert accountant, had solved the mysteries of computing and calculating." [15] In its next issue the paper declaimed against the "absurd mathematical intricacies" and observed that under the system "it is possible for a candidate who has two or more opponents to be defeated even though the ballots show he received the largest number of 'first choice' votes." [16]

The system survived the criticism and was used in the next four elections. There were no contests in the years 1929–31 inclusive, but in 1932 the city witnessed a repetition of the trouble of 1928. The same two prominent candidates again competed in a three-cornered contest. Voting manipulation was openly charged. One of the prominent candidates was accused of entering the third candidate for the purpose of jeopardizing his rival's position under the Nanson count. These tactics, which obviously had originated in 1928, failed in the present election. The defeated candidate of 1928 won a seat on the council, but declared that he would immediately move the repeal of the ordinance under which the system had been adopted.

Criticisms were renewed, and all groups agreed that the dangers of vote manipulation could no longer be disregarded. The *Mining Journal* remarked editorially, "It may be a good system mathematically, but politically it is all wrong . . . ." [17] In the same issue a city official was reported to have said that, had the supporters of the two prominent candidates cast only third choices for the leading rival, the third candidate would have won the election, without the benefit of any substantial political support. The last-

[15] December 5, 1928. [16] December 6, 1928. [17] December 7, 1932.

place candidate criticized the method of the count and denounced the entire plan. He insisted that the voters in certain sections of the city were not able to vote the preferential ballot. Complaints were directed also against the excessive cost of the system.

The ordinance was repealed on February 27, 1933, and after fifteen years' experience with preferential voting Marquette returned to plurality elections. The extended duration of the experiment may be ascribed to infrequent election contests rather than to any real satisfaction with the method. During the fifteen years only three elections provided contests in which it became necessary to use the Nanson count to determine the winner. In each of these elections the winning candidate polled a plurality of first-choice votes. Each contested election was followed by a storm of criticism and demands for the abandonment of preferential voting.

An analysis of the criticisms reveals that the system was indicted on no less than seven counts: (1) It was too costly; (2) The count was too complicated; (3) The system was illegal and unconstitutional; (4) The preferential ballot was not understood; (5) The voter required and demanded only one choice; (6) A candidate who polls a plurality of the first choices should win; (7) Voting could be manipulated to prejudice the position of an otherwise strong candidate.

Almost all of these charges are inconsequential and can be summarily dismissed. The cost of the elections during the years 1926–32 under the Nanson system was approximately from fifty to seventy-five dollars less per year than the combined annual costs of the primary and election in the succeeding six-year period. A certified accountant was a member of the board, but to insure expertness and accuracy, rather than because of the intricacies of the count, which was usually completed within a few hours. The constitutional issue was raised in the early years; no court challenge was instituted, and the issue was apparently forgotten. Of the remaining charges, the last is the only one which cannot be dismissed as of that vague general type of criticism frequently directed against innovations in government. The charge of vote manipulation appears substantiated. There were evidences of ill will and bad temper. The system might, however, have survived had certain weaknesses, revealed in 1928 and emphasized in 1932, not been discovered.

Marquette, like almost every other American community, selects

its officers, if not actually from, at least with the tacit consent of, the substantial elements of its population. Marquette, like every other community, has a population element which votes but is not ordinarily permitted to govern. In times of economic crisis these class-conscious groups demonstrate a tendency to regard political action as a legitimate means of self-help. In the minds of many persons the Nanson system, with the petition method of nomination, the preferential ballot, and the point computation, afforded an excellent opportunity for "the wrong people" to get into office. It is entirely possible that the system failed because it threatened actually to substitute majority for plurality rule as the basic tenet of representative government.

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GEORGE BANCROFT AND HIS THEORY OF HISTORY

RUSSEL B. NYE

"TO BE a really great historian," said Macaulay, "is perhaps the rarest of intellectual distinctions." George Bancroft, besides being a politician, poet, literary critic, and diplomat, found time to become the first great historian of America, and was certainly conceded a position of primary importance by his own time if not by a later one. The development of new methods, of new approaches, of new emphasis upon different factors has left the historical writings of Bancroft behind. His great *History of the United States from the Discovery of the Continent*, the product of sixty years' labor, has been outmoded by the work of a later generation of scholars, but it still remains the pioneer attempt to portray the entire sweep of American history, a work which laid the foundation for most of the historical writing in America which followed it and built upon it. We can find much today to criticize in Bancroft's volumes,[1] but when we view his work as representative of the life and times during which he wrote, as the product not only of his own intellect and art but of the distinctive tone and temper of the early and middle nineteenth century, we place his contributions in their proper position within the stream of American historical writing past and present, and evaluate their importance with a greater degree of respect and appreciation.

It is not the intent of this paper to attempt a criticism of Bancroft's historical work or to point out its shortcomings from a modern point of view. It is aimed, instead, at presenting some of those views concerning history and the historian which tempered and conditioned his work, and which led him to write the history of the United States as he did. We must think of Bancroft as the product

[1] See, for example, the excellent studies of N. H. Dawes and F. T. Nichols, "Revaluing Bancroft," *New England Quarterly*, 6 (1903) : 278–293, and of Watt Stewart, *The Marcus W. Jernegan Essays in American Historiography* (1937), edited by W. T. Hutchinson.

of his age — of the age of Emerson, Thoreau, Longfellow, Bronson Alcott, Margaret Fuller, and the rest, of the quarter century before Darwin's *Origin of Species*, of the era of expansion outward and upward intellectually — and as the exemplification of certain aspects of that age. Men had treated of American history before Bancroft, men such as Abiel Holmes, Benjamin Trumbull, the Italian Charles Botta and the Scotsman James Grahame, Timothy Pitkin, and Bancroft's friend Jared Sparks, but none of them had written of it as Bancroft began to write of it in 1834, for he wrote from the viewpoint of the transcendentalist. The key to an understanding of his historical theory lies in a broader understanding of the religious and philosophical ideas upon which his historical writing was based and which gave rise to his controlling ideas of nationalism and democracy.

It is not to be forgotten that George Bancroft was intended for the ministry, and that until he was twenty-three he was educated to follow in the footsteps of his father Aaron, whose *Life of Washington* (published in 1807 and second in popularity only to Parson Weems' biography) and whose long career as a liberal Congregational-Unitarian divine no doubt strongly influenced his son's intellectual development. Accounted a promising theological student at Harvard, Bancroft was sent abroad by the college in 1818 to complete his studies at Göttingen in Germany, where he remained until 1821. During his stay abroad he came into contact with the essentials of American transcendentalism before they had left German shores; he read Kant, Fichte, Jacobi, Schelling, and Novalis, studied with Schleiermacher and Hegel, and, at a time when few Americans could read German, gained a wide acquaintance with German literature and philosophy some years before Emerson and others realized its importance. Returning to teach at Harvard for a year, he joined Joseph Green Cogswell in 1823 in founding Round Hill School, an experimental secondary school patterned upon European educational theory. After teaching for nine years at Round Hill, he retired to write history, the first volume of his *History of The United States* appearing in 1834. A year later, in an essay called *The Office of the People in Art, Government, and Religion*, he explained for the first time the philosophy which underlay his approach to history, and in 1854, shortly after the publication of the sixth volume, he completed his explanation in an essay called *The Necessity, the Reality, and the*

Promise of the Progress of the Human Race.[2] It is to these essays and to the supporting evidence of his correspondence and the *History* itself that one must turn for a full understanding of his essentially transcendentalist philosophy of history.

The earlier essay, *The Office of the People* . . ., stated clearly for the first time the thesis that was to motivate all of Bancroft's constructive thought in politics, criticism, ethics, and history, that is, an unbounded faith in mankind and in its natural goodness. By divine order, he believed, there had been implanted in mankind the faculty of Reason, by which man could unerringly discern truth and goodness, beauty and justice. Since this faculty was common to all men, it followed in Bancroft's reasoning that the democratic system of government was most trustworthy, that the common people composed the highest earthly tribunal in all matters relating to their welfare. Upon closer examination it appears that this Reason, this source of divinely inspired truth, was to Bancroft not a rational but an *intuitive* power, the familiar Reason of the transcendentalists, of Emerson, and of Coleridge, and of the early American understanding of Kant. "I mean not that faculty," said the historian in explanation,[3] "which deduces inferences from the experience of the senses, but that higher faculty, which from the infinite treasures of its own consciousness, originates truth, and assents to it by the force of intuitive evidence; that faculty which raises us beyond the control of time and space, and gives us faith in things eternal and invisible."

In the second essay, continuing the line of thought begun earlier, he went on to prove that, since man had within him this God-given power, he could not fail to progress, as God had so planned, by perceiving and following the divine truth it revealed. The reality of that progress he confirmed by a lengthy contrast between past and present conditions in art, government, society, science, and related fields of human endeavor. Thus the two essays, taken as a unit, expressed the three basic ideas of the transcendentalist philosophy: a faith in natural goodness, a dependence upon intuitive Reason, and a belief in the tendency of mankind to progress.[4]

[2] These and other fugitive essays on various subjects Bancroft collected and published in *Literary and Historical Miscellanies*, 1855.

[3] *The Office of the People* . . ., in *Literary and Historical Miscellanies*, p. 408.

[4] For a discussion of Bancroft's religious ideas, their relation to transcendentalism, and his place among the pioneer transcendentalists see R. B. Nye, "The Religion of George Bancroft," *Journal of Religion*, 19 (1939): 216–234.

The intuitive power which Bancroft and the transcendentalists named Reason provided, Bancroft explained, the perceptive faculty necessary both to the poet and to the historian. Applied to the study of present and future events, it produced the poet, who, as Bancroft defined him, was merely a mouthpiece for the messages of the Infinite, which he received through his finely developed and attuned intuitive gift.[5] The historian similarly made use of Reason, but with the significant difference that he applied it to the study of past action, and perceived in the past the workings of the Infinite Mind. To Bancroft the office of the historian was nearly as noble as that of the poet:[6]

> It is because God is visible in history that its office is the noblest except that of the poet. . . . History, as she reclines in the lap of eternity, sees the mind of humanity itself engaged in formative efforts. . . . Of all the pursuits that require analysis, history, therefore, stands first. It is equal to philosophy; for as certainly as the actual bodies forth the ideal, so certainly does history contain philosophy. It is grander than the natural sciences; for its study is man, the last work of creation, and the most perfect in its relation with the Infinite.

The office of the historian, Bancroft believed, was twofold. First, he examined the past to find proof of the relative correctness of man's intuitive perception of divine moral law. History, then, was the record of man's attempts to receive from God certain ideas of truth, morality, beauty, and justice, and the historian presented the evidences of his success:[7] "From the depths of man's consciousness, which envelops sublimer truths than the firmament over his head can reveal to his senses, rises the idea of right; and history, testing that idea by observation, traces the vestiges of moral law . . . in every age, proves experimentally the reality of justice, and confirms by induction the intuitions of Reason." Second, the historian examined the past to find there indications of man's progress as planned by God; history was also the record of the unfolding of the divine plan for the human race, and the aim of the historian was to perceive and explain its significance:[8] "The inference that there is

[5] *The Necessity, the Reality, and the Promise of Progress of the Human Race*, in *Literary and Historical Miscellanies*, p. 493. "The poet . . . catches the first beam of light that flows from its uncreated source. He repeats the message of the Infinite, without always being able to analyze it, and often without knowing how he received it, or why he was selected for its utterance." Compare Emerson's idea that poetry is simply "an influx of the Divine Mind into our mind."

[6] *Ibid.*, p. 494. [7] *History of the United States*, 1876 edition, V: 70.

[8] *Ibid.*, II: 545.

progress in human affairs is warranted. The trust of our race has ever been in the coming of better times. Universal history does but seek to relate 'the sum of all God's works of providence.'"

The historian had to read the past, then, in terms of the common man, of the progress of the mass of humanity, since all men are endowed equally with intuitive Reason and the ability to progress. History had to be read and written in terms of the democratic multitude, and in analyzing the past the historian had to ask himself constantly, Did this or that event mark a step forward for the common man? "The exact measure of the progress of civilization is the degree in which the intelligence of the common mind has prevailed over wealth and brute force; in other words, the measure of the progress of civilization is the progress of the people." [9] To Bancroft historical writing meant, therefore, perceiving and interpreting for and to mankind the plans of God; the historian's function, analogous to that of the churchman, was basically religious, for as he said, "Each page of history may begin and end with Great is God and marvellous are his doings among the children of men." [10]

In Bancroft's historical theory, therefore, history found unity and continuity through its existence in the Deity, each event of the past being but a functional part of the entire organism planned by God. The historian recognized and explained this continuity of the stream of events, perceiving God's plans in previous action and ascertaining those facts about the past which, "placed in proper contiguity, become of themselves the firm links of a brightly burnished chain, connecting events with causes, and marking the line along which the power of truth is conveyed from generation to generation." [11] The historian's perception, unlike that of the poet, was in Bancroft's view based on logic as well as on intuitive Reason, for the historian cannot, like the poet, "assume to know intuitively the tendency of the ages." Therefore "his research must be un-

[9] "*The Progress of Mankind*," *op. cit.*, p. 486. Bancroft made use of the "fixed-point" idea in history long before Henry Adams, using acts of religious toleration and political democracy as points from which to measure progress.

[10] Howe, M. A. De Wolfe, *Life and Letters of George Bancroft*, I: 199. Bancroft made the statement in 1832, at about the time he began work on the first volume of the *History*.

[11] *History*, 1876 edition, II: 324 and 354, gives a full explanation of Bancroft's arguments.

wearied, and conducted with indifference" if the divine truth is to be gained from the study of the past. Thus [12]

> By comparison of document with document; by an analysis of facts, and the reference of each of them to the laws of intelligence which it illustrates; by separating the idea which inspires combined events with the great movements of nations — historic truth may establish itself as a science, and the principles that govern human affairs, extending like a path of light from century to century, become the highest demonstration of the superintending providence of God.

The guiding principles beneath Bancroft's historical writing thus lay in these typically transcendentalist beliefs held by the historian, that history was but the record of a divine plan manifested in the past, and that the divine plan revealed that mankind was intended by God to progress toward a future state wherein principles of truth, justice, beauty, and morality — perceived intuitively through Reason — might guide and raise it. In writing the history of the United States Bancroft treated it as nothing more than an illustration of and a step in that steady march of humanity toward the divinely perfect state. "Each people that has disappeared," he said, "every institution that has passed away, has been but a step in the ladder by which humanity ascends toward the perfecting of its nature." [13] It was the office of America, he explained, to contribute as its part of the steady pervasive flow of progress the principles of freedom, equality, and democracy in government; America carried out this one phase of the whole unified plan of the Divine Mind for man's ultimate attainment of the perfect world.[14] Since the Revolutionary War marked the transformation of this tendency into actual fact, Bancroft therefore tended to treat all American history preceding it as merely an introduction to it, and postwar history through the Constitutional period as its solidification and concrete embodiment in reality.[15]

The distinguishing characteristics of George Bancroft's historical

[12] *History*, 1876 edition, II: 544–546. Since the historian treats of the acts of the Deity in the past, prejudice or carelessness partakes of irreverence as well as bad scholarship.

[13] *Ibid.*, III: 8. The first ten pages of this volume comprise a complete and highly important statement of this idea as the author applied it to the study of American history.

[14] See especially the long passage in Volume IV, pp. 311–314, of the 1876 edition, for Bancroft's recognition of this idea as the guiding principle of his historical work.

[15] As early as Volume III, p. 10, Bancroft spoke of "the American Revolution, of which I write the history . . . ."

writings stemmed either directly or indirectly from his religious ideas, which were primarily transcendentalist. His belief in the inherent goodness of mankind led him to express as the theme of his histories the trust in democracy and the belief in the worth of the common man that every reader of his volumes recognizes. Buttressing his democratic convictions, and forming the foundation for his belief in progress, was his essentially Emersonian faith in the ability of man to perceive truth through his innate Reason; from this central principle arose, too, his concept of the historian as the man who intuitively sees the hand of God visible in the past. Less directly related to his religious ideas was his historic nationalism. He visualized from his transcendentalist viewpoint the pattern of history as the steady and inevitably progressive flow of events toward a divinely planned world state, and nothing could be more natural for the son of an era of westward movement and the awakening of national self-consciousness than to choose the United States as the leader in the march of destiny. Bancroft simply wrote the history of the United States as the age of Emerson and Jefferson and Jackson would have it written, in the temper of the nineteenth century's Golden Day. We cannot appreciate or evaluate his viewpoint fully because between his time and ours is interpolated a revolution in thinking, the result of Darwinism, industrialism, civil war, and new directions in historiography, but an understanding of what Bancroft was attempting to do and show in his historical writings, a survey of the origins of his theory of history, may help us to a more sympathetic attitude toward his work and an appreciation of his greatness.

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SOME ASPECTS OF CONSTITUTION MAKING IN MICHIGAN

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MICHIGAN has had three constitutions, those of 1835, 1850, and 1909. Two others were prepared, in 1867 and in 1873, but were defeated decisively. Proposals for calling constitutional conventions failed in 1882, 1890, 1892, 1893, 1904, 1926, and 1942.[1] In addition, constitutional amendments have been voted upon frequently since 1835, averaging nearly two each year.

A study of these five constitutions and the proposed amendments reveals the evolution of democratic political thought during a century of American expansion and growth. This statement should be qualified by noting that the constitution of 1835 resisted the Jacksonian dogmas of popular election of state administrative officials.

Spatial limitations will not permit a thorough analysis of the provisions of each of these documents and amendments, but some observations, comparisons, and conclusions will be made, especially with regard to the three that were adopted.

The constitutions of most of the states after 1789 followed an enabling act of the Congress of the United States, but in Michigan the constitution preceded the enabling act by several months.[2] The boundary dispute, the "Toledo War" (or the "Ohio War"), the compromise involving the Upper Peninsula, and the first and second "conventions of assent" explain, in large part, the delay in the admission of Michigan to statehood until 1837. The legal position of Michigan during this interval was of importance in the presidential election of 1836.

The Constitution of 1835 does not include a bill of rights as such, but Article I does contain provisions whose lineage stems from

[1] Thorpe, F. N., *The Federal and State Constitutions, Colonial Charters, and Other Organic Laws of the States, Territories, and Colonies . . .*, IV: 1977–1979, and *Michigan Official Directory and Legislative Manual*, 1941, p. 86.

[2] Constitution adopted November 2, 1835. The enabling act was passed by Congress on June 15, 1836.

the Connecticut bill of rights and from the first ten amendments to the federal constitution. Samples of these provisions are: "All political power is inherent in the people"; "No man or set of men are entitled to exclusive or separate privileges"; "The military shall, in all cases, and at all times, be in strict subordination to the civil power"; "All acts of the legislature contrary to this or any other article of this constitution shall be void." [3]

The state's second fundamental law also failed to provide a bill of rights, but many of the provisions ordinarily contained in such a bill are to be found elsewhere in this document, especially in the sections dealing with the legislative and the judicial departments, and even more so in Article XVIII, captioned "Miscellaneous Provisions."

The present constitution has a "Declaration of Rights" whose twenty-one sections were taken largely from its predecessor, thirteen of them verbatim. The only new section reads as follows: "All political power is inherent in the people. Government is instituted for their equal benefit, security and protection." [4]

When the machinery of government set up under the various constitutions is examined it will be noticed that, broadly speaking, the composition of the state legislature has undergone a minimum of change. In the first constitution the membership of the house of representatives was fixed at not less than 48 nor more than 100, and the senate at one third of the number of representatives. The Constitution of 1850 provided for a house of from 64 to 100 members. No changes were made in the membership of either house by the present constitution. It may be interesting to note that the proposed constitutions of 1867 and 1873 raised the upper limits of the house of representatives to 110 and the term of senators to four years, one half of whom were to be chosen every two years.

Changes in the powers and duties of the legislative body have been more pronounced than those relative to its composition. By 1850 the people of Michigan discovered that they had overestimated the competence of legislators; consequently, their second constitution placed several restrictions upon legislative action. This is especially noticeable in matters dealing with finance, debts and their

[3] Dorr, Harold M., *The Michigan Constitutional Conventions of 1835–36*, Appendix C.

[4] Constitution of 1909, Art. II, Sec. 1.

limitation, sinking funds, assessment of property, and education. The clause in the first constitution that encouraged internal improvements was omitted from subsequent documents. Many grants of power were shackled by detailed restrictions upon their exercise. In addition to several amendments concerning legislative powers or restrictions, the Constitution of 1909 contains two clauses that accentuated the diminishing loss of legislative prestige. One of these provides for the proposal of amendments by petitions of the electorate; the other permits the governor to veto items in appropriation bills.

Provision for the remuneration of members of the legislature has been a hardy perennial in the several constitutional conventions and in numerous amendments. In the first constitution the compensation was "to be ascertained by law" and should "never exceed three dollars a day." [5] There is no direct statement about its interpretation, but the context leads this writer to believe that it meant "three dollars a day" for the time it was actually in session. Any ambiguity that might arise from this phraseology was avoided in the Constitution of 1850, which said that the members should be paid "three dollars a day for actual attendance, and when absent on account of sickness, for the first sixty days of the session" of 1851 and "for the first forty days of every subsequent session, and nothing thereafter." [6] (Apparently legislative junkets had not been devised in 1850!)

No mention of pay for transportation appears in the first constitution, but it is provided for in the Constitution of 1850. Compensation to members for attendance upon extra sessions was fixed at "three dollars a day for the first twenty days, and nothing thereafter." For attendance upon any session members of the legislature "shall be entitled to ten cents and no more for every mile actually traveled . . . on the usually traveled route." Other perquisites included an allowance not to exceed five dollars for stationery and newspapers "for each member during any session." [7] The Constitution of 1909 changed the basis of remuneration from a per diem rate to eight hundred dollars "for the regular session," and

[5] Constitution of 1835, Art. IV, Sec. 18.

[6] Constitution of 1850, Art. IV, Sec. 15.

[7] *Ibid.*, Art. IV, Sec. 16. The legislature was authorized to provide "for the payment of postage on all mailable matter received by its members and officers during the sessions of the Legislature, *but not on any sent or mailed by them.*" (Italics mine.)

for an extra session, five dollars per day "for the first twenty days and nothing thereafter."[8] By an amendment this provision was changed to read "$3 per day" and made to apply for every day of the term.

The passing years have witnessed changes in the selection of the executive and administrative officers of the state. In the first constitution provision was made for the election of the governor and lieutenant governor only. Of the six other state administrative officers five were to be appointed by the governor and the senate; the sixth, the treasurer, was to be chosen by a joint vote of both branches of the legislature. By 1850 frontier democracy was strong enough in Michigan to place all officials on the elective list. It is also to be pointed out that another aspect of the democratic creed, the practice of short terms, was a part of the program throughout the period under review. The Constitution of 1850 shows further evidence of progressive democracy in providing for the election of five county officers and a maximum of nine township officers.[9]

The powers of the governor have not changed greatly during the period of statehood. The most significant innovation made by the Constitution of 1850 was the substitution of election for appointment in the case of five state officers of administration and of the judges of the supreme court. The Constitution of 1909 increased the power of the governor by permitting the veto of items in appropriation bills. The lieutenant governor was given the casting vote by the first and second constitutions, but was denied it by the third. No other state denies its lieutenant governor this power.

Nothwithstanding the growth of the administrative services and the development of new techniques, Michigan has done little to modernize the administration of her government. Measured by the standards set and the results obtained by Illinois, New York, Ohio, Pennsylvania, Virginia, and Tennessee, among others, this phase of the government of Michigan is quite antiquated.[10] The lack of a centralization of executive and administrative power in the governor

[8] Constitution of 1909, Art. V, Sec. 9.

[9] Constitution of 1850, Art. X, Sec. 3, and Art. XI, Sec. 1. The list of nine township officers referred to above does not include the overseers of highways, one of whom was elected from each highway district in the township.

[10] A gesture was made in the direction of reorganization in 1921 by the creation of the state administrative board. This is an *ex officio* board consisting of the eight elective administrative officials of the state.

makes it difficult for that official to be much more than simply *primus inter pares*. The numerous quasi-independent boards and commissions of the present day remind us that some overhauling might demonstrate that change and progress are not necessarily incompatible.

The question of remuneration for the services of the state's administrative officials has had few closed seasons during the century of statehood. It was a lively issue in each of the five constitutional conventions and in several campaigns for amendments. The framers of the first constitution were content to give the legislature power to determine the salary of the governor, with the provision that such remuneration could not be increased or diminished during the term for which he was elected.[11] The lieutenant governor was to receive the same remuneration as the speaker of the house of representatives. No provision was made for the salaries of the other administrative officers.

The Constitution of 1850 included an article on "salaries," by which the governor, the state treasurer, and the superintendent of public instruction were to receive $1,000 each; the secretary of state, the attorney general, and the commissioner of the land office, $800 each. These officers were forbidden to retain fees.[12]

The defeated constitutions of 1867 and 1873 provided for increases in the salaries of several of the state officials. The provisions were quite unpopular, especially the one of 1873, partly because it was a contemporary of the rather malodorous "salary grab" at Washington. In the Constitution of 1909 the governor and the attorney general were given salaries of $5,000 each; the secretary of state, the auditor-general, the state treasurer, and the commissioner of land office (an office which the legislature was empowered to discontinue) were given salaries of $2,500 each. No fees were permitted. A further provision reads, "It shall not be competent for the legislature to increase the salaries herein provided," [13] a clause which to a layman, at least, appears to have been stretched wellnigh to the breaking point in recent years.

Provisions concerning the judicial aspects of government have

[11] Constitution of 1835, Art. V, Sec. 18.

[12] Constitution of 1850, Art. IX, Sec. 1.

[13] Constitution of 1909, Art. VI, Sec. 21. *Michigan Manual* (as cited in note 1), 1911, p. 43. This *Manual* gives the Constitution of 1909 and shows changes from that of 1850 as amended to 1908.

changed materially in the documents under consideration. These changes appear in both the composition and the procedure provided for the judicial bodies. In the first constitution the article on the judiciary contained seven sections; but the Constitution of 1850 lengthened the article to thirty-five sections, several of which prescribed procedure in minute detail. The provisions in the present constitution relative to the judicial department presented no significant changes save the elimination of the sections concerning the Upper Peninsula.

The clause on the judiciary in the first constitution parallels almost verbatim that of the federal constitution, viz., that "the judicial power shall be vested in one Supreme Court, and in such other courts as the legislature may, from time to time, establish." [14] Provision was also made for a probate court in each organized county and for four justices of the peace in each township. Judges of the supreme court, whose number was not stipulated, were to be "nominated and, by and with the advice and consent of the senate, appointed by the governor" for a term of seven years and were to receive "adequate compensation," which could not be decreased "during their continuance in office." Probate judges, associate judges of circuit courts, and all judges of county courts, together with the justices of the peace, were to be elected for a term of four years by the qualified voters of their respective areas.

The Constitution of 1850 clearly states the grades of courts as follows: "The judicial power is vested in one supreme court, in circuit courts, in probate courts, and in justices of the peace." The legislature was authorized to establish "municipal courts of civil and criminal jurisdiction." The supreme court was given "a general superintending control over all inferior courts." [15]

The state was to be divided into eight judicial circuits, in each of which a judge was to be elected for six years. The supreme court consisted of these circuit judges, four of whom made a quorum. The concurrence of three was necessary for a final decision. This plan was to continue for at least six years, after which the legislature might provide for a supreme court composed of one chief justice and three associate justices popularly elected. The latter arrangement was to remain for at least eight years. The Constitution of 1850

[14] Constitution of 1835, Art. VI, Sec. 1.
[15] Constitution of 1850, Art. VI, Secs. 1 and 3.

further provided that the office of master in chancery be abolished.[16] The proposed constitution of 1867 made few changes in the judiciary; the one of 1873 called for a fifth justice of the supreme court.

The clause describing the court system in the present constitution is strikingly similar to that of 1850. One phrase, however, demands attention. The Constitution of 1909 states that no court may be established by statutory action except by a two-thirds vote.[17]

Territorial laws and the several constitutions gave considerable attention to local government, especially to rural government. This was to be expected from a community founded by pioneers with a New York and New England background.[18] In 1835 provisions were made for the biennial election of the following county officers: sheriff, treasurer, register of deeds, surveyor, and one or more coroners. The sheriff might not serve more than four years out of six, and the county was not responsible for his acts. Each township was to elect four justices of the peace for four years, with staggered terms. The legislature might increase this number in "all incorporated towns, or cities."[19] In the formation of new counties no organized county could be reduced "to less than four hundred square miles."[20]

The state's second constitution made detailed plans for county and township government. The county was declared to be "a body corporate, with such powers and immunities as shall be established by law." The organization of new townships should not reduce the number of organized townships of any county below sixteen, except by a majority vote in each county affected by it.[21] The general administrative affairs of the county were allocated to a board of supervisors, consisting of a supervisor from each township and such representation from cities as might be determined by law. These boards might "borrow or raise by tax" a sum not to exceed $1,000 in any one year "for constructing or repairing public buildings, high-

[16] *Ibid.*, Art. VI, Sec. 5. For subsequent statutory changes see Thorpe, *op. cit.*, p. 1952, note b.

[17] Constitution of 1909, Art. VII, Sec. 1.

[18] Dorr, *op. cit.*, p. 28. Footnote 1 shows that of the 72 delegates of the convention of 1835 whose biographies are obtainable 42 were born in New York and New England, 7 in Pennsylvania, 5 in New Jersey, 5 in Michigan. Nine were born in foreign countries.

[19] Constitution of 1835, Art. VII, Sec. 4; Art. VI, Sec. 6.

[20] *Ibid.*, Art. XII, Sec. 7.

[21] Constitution of 1850, Art. X, Secs. 1 and 2.

ways or bridges." [22] Greater sums for such purposes required a majority vote of the people. The number of elective county officers remained the same as it had been in 1835, for, though the office of coroner was dropped, that of clerk was added. County boards might unite the officers of clerk and register of deeds or "disconnect the same."

By the Constitution of 1850 townships also became corporate bodies. Each township was to be staffed by the following officials, elected annually: supervisor, clerk, who was *ex officio* school inspector, highway commissioner, treasurer, one overseer of highways for each highway district, school inspector, and from one to four constables.[23]

Local government — this time, both rural and urban — also evoked detailed discussion in the convention of 1908. Most of the changes relative to counties came from rephrasing and rearranging provisions of the immediately preceding constitution. The population requirement for a city that desired to become a separate county was increased from twenty to one hundred thousand. Two new provisions created a "board of jury commissioners" and permitted counties, either alone or by uniting, to provide funds for eleemosynary institutions, and directed that "all county poor houses shall hereafter be designated and maintained as county infirmaries." [24] The prosecuting attorney was added to the list of elective county officials. Few changes were made in the organization and powers of townships except the abolition of the office of school inspector and the addition of a section restricting the granting of franchises to public utilities.[25]

For the first time in the constitutions of the state villages and cities received special consideration. Their powers and limitations may be summarized briefly as follows: A general law provided for the incorporation of villages, and another for the incorporation of cities. In each instance limitations were placed upon taxation and indebtedness. Cities and villages were empowered to "acquire, own, establish and maintain," both within and without their corporate limits, "parks, boulevards, cemeteries, hospitals, almshouses and all

[22] *Ibid.*, Art. X, Secs. 6, 7, and 9.
[23] *Ibid.*, Art. XI, Secs. 1 and 2.
[24] Constitution of 1909, Art. VIII, Sec. 11.
[25] *Ibid.*, Art. VIII, Secs. 18 and 19.

works which involve the public health or safety." No municipality could grant a franchise or a license for more than thirty years.[26]

The important rôle of Michigan in the development of the American system of education inspires particular interest in the provisions that her constitutions contained relative to schools. It would be difficult to disagree with Professor Dorr's conclusion that "the constitution of 1835 carried a complete and enlightened article on public education." [27] The legislature was to encourage "by all suitable means, the promotion of Intellectual, Scientifical, and Agricultural improvement." [28] Proceeds from the sale of public lands were to become "a perpetual fund," the interest from which was to be "inviolably appropriated" to help maintain at least three months of school throughout the state. Districts failing to contribute their part were to lose their portion of the subsidy. A superintendent of. public instruction was to be appointed by the governor (the appointment to be ratified by the legislature) for a term of two years. As soon as the circumstances of the state would permit the legislature was to maintain libraries, "one at least," in each township, to be financed from fines exacted for breach of the peace and sums paid for exemption from military duty. Funds from the sale of certain lands were to be used "for the support of a University . . . with such branches as the public convenience may hereafter demand for the promotion of literature, the arts and sciences." [29] Truly, there were giants in those days!

The Constitution of 1850 made important changes in the article on education. A board of regents consisting of one member from each of the judicial districts was made the governing body of the University. The interest on funds from lands that escheated to the state was to be applied to the primary school fund. All instruction in these primary schools "shall be conducted in the English language." A state board of education, consisting of three members elected for six years, was given general supervision over the "State Normal School" and was to perform such other duties as were prescribed by law. Institutions for the deaf, dumb, blind, and insane "shall always be fostered and supported." The legislature, "as soon as practicable," was to provide for the establishment of an agricultural school and might "make the same a branch of the

[26] *Ibid.*, Art. VIII, Secs. 22 and 29.
[27] Dorr, *op. cit.*, p. 32.
[28] Constitution of 1835, Art. X, Sec. 2.
[29] *Ibid.*, Secs. 4 and 5.

University" and place it "under the supervision of the regents of the University."[30] The superintendent of public instruction became an elected official.

The Constitution of 1909 created an elected state board of agriculture of six members to have "general supervision" of the agricultural college and "control of all agricultural college funds," placed the superintendent of public instruction on the board of education and on the board of regents, and made him an *ex officio* member of all other boards having control of public education in state institutions.[31] The legislature was authorized to "maintain the university, the college of mines, the state agricultural college, the state normal college and such state normal schools and other educational institutions as may be established by law."[32]

As might be inferred, the amending clause in each of these constitutions reflects the evolution of the democratic processes in the country as a whole.

In the state's first constitution amendments or proposals of amendments might originate in either house of the legislature and, if favored by a majority of those elected to each house, were referred to "the legislature next to be chosen," provided three months had elapsed. Such proposals as received a two-thirds vote of all members were submitted to the voters. To become a part of the constitution the proposed amendment had to be approved by a majority of all electors voting thereon. By a two-thirds vote the legislature might at any time recommend to the electors the question of calling a convention "to revise or change this entire constitution."[33]

The process of amendment or revision under the Constitution of 1850 was somewhat simpler and rather more democratic than that of its predecessor. Proposals that received the support of two thirds of the members were submitted to the electors at the next spring or autumn election "as the legislature shall direct," and became valid if supported by a majority of qualified electors voting thereon. As has already been noted, the legislature was required to submit to the electorate the question of calling a constitutional convention every sixteen years.[34]

[30] Constitution of 1850, Art. XIII, Secs. 2, 4, 6, 10, and 11.

[31] Constitution of 1909, Art. XI, Secs. 2, 7, and 8.

[32] *Ibid.*, Sec. 10. [33] Constitution of 1835, Art. XIII, Sec. 2.

[34] Constitution of 1850, Art. XX, Secs. 1 and 2, *Compiled Laws*, Michigan, I: 77. This volume was compiled and arranged by Thomas M. Cooley, 1857. The

The Constitution of 1909 made no change in the then existing method by which amendments were proposed by the legislature and acted upon by the voters. A lengthy section permits, however, the origination of amendments by the use of petitions.[35] The question of a constitutional revision was to be submitted to the electorate in 1926 and "in each sixteenth year thereafter." [36]

Perhaps this brief and incomplete analysis of the fundamental laws of Michigan may well be followed by an equally brief summary in regard to each of them.

A careful student of the Constitution of 1835 says that "considered as a whole . . . it was brief and concise, admirably adapted to the needs of a people undergoing rapid political change." [37] A member of the convention that framed it declared that it contains "not a solitary superfluous paragraph or even a phrase," and that it is "one of the most plain, finished and republican instruments to be found in the Union." [38]

The second constitution of Michigan was twice the length of its predecessor. In this respect it reflected the rather prevalent mid-century inclination to depart from the more fundamental principles of constitutional government and to incorporate provisions that might more wisely be left for statutory enactment. That this tendency was not unobserved at the time is attested by the remarks of an able contemporary critic. He said that the Constitution of 1835 "was very simple and very much better adapted to the changing necessities of a growing state than the present one" (that of 1850), and commended the members of the convention of 1835 for leaving "to the legislature broad discretion." [39]

Viewed in its entirety the constitution proposed in 1867 did not make a radical departure from that of 1850.[40] One of its novel proposals was that the governor and the lieutenant governor should be

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student will discover that authorities differ in the use of capital letters and punctuation. For the Constitution of 1835 the present writer has followed Dorr; for that of 1850, T. M. Cooley, *The Compiled Laws of the State of Michigan* (Lansing, 1857), and Thorpe, *op. cit.;* and for the present one, *Michigan Manual*, 1911.

[35] Constitution of 1909, Art. XVII, Sec. 2.

[36] *Ibid.*, Sec. 4.

[37] Dorr, *op. cit.*, p. 29.

[38] Edward D. Ellis, a delegate from Monroe. Quoted by Dorr, *op. cit.*, p. 29.

[39] Judge James Campbell, quoted by Dorr, *op. cit.*, p. 29, note 1.

[40] Cf. Shilling, D. C., "The Michigan Constitution of 1908; or Constitution Making since 1850," *Michigan History Magazine*, 18 (Winter Number, 1934) : 35.

elected from a single list of candidates. This method had proved unsatisfactory in the election of the president and the vice-president of the United States. A defeated proposal, the discussion upon which was called "the most bitter of all the debates," was that calling for the union of the Agricultural College with the University of Michigan. Suffrage for women was another rejected proposal. This convention furnished a fine point of law in regard to the oath to be taken by the delegates whose mission was to modify or to displace a constitution that they had solemnly sworn to uphold. A new form of oath permitted them to support the Constitution of the United States and the constitution of the State of Michigan and to discharge faithfully the duty of delegate to the convention.[41] The president of the convention in his farewell address declared: "The Constitution you are now about to submit . . . is, taken as a whole, a decided improvement upon the Constitution now in force."[42] The voters thought differently and rejected it decisively.

Sentiment in favor of changes gathered momentum during the following five or six years. This trend is seen in the proposal of nine amendments and in the adoption of four of them. A joint resolution of the legislature in 1873 authorized the governor to appoint a Constitutional Commission consisting of two members from each of the nine congressional districts of the state. Some of the proposals of this Commission were echoes of 1867; some were new. A few of the most important ones were: a four-year term for senators, one half retiring every two years; an increase in the membership of the house of representatives; salary increases for state officials; item veto by the governor in appropriation bills (born thirty years too soon); the regulation of railroad rates; and the opening to women of the offices of notary public and register of land. The principle of the short ballot, accepted by the first constitution and rejected by the second one, was recognized in the proposal for the appointment of circuit judges.[43]

As a summary concerning the Constitution of 1909 the pamphlet prepared by the convention to explain its work is invaluable.

The people were told that the revision "follows closely the lines

[41] *The Debates and Proceedings of the Constitutional Convention of the State of Michigan, Convened at the City of Lansing, Wednesday, May 15th, 1867* (Lansing, 1867), I: 2.

[42] *Ibid.*, II: 1023.

[43] For a more detailed statement of the constitution of 1867 and 1874 see the author's account, *op. cit.*, pp. 34–37.

of the present constitution . . . that the changes proposed are either necessary or expedient to meet new conditions or to make more certain the provisions of the constitution of 1850." The convention studiously sought "to leave matters purely legislative in character to be dealt with by the legislature since error in the constitution may continue indefinitely, while error in legislation admits of speedy correction." [44] The changes from the instrument of 1850 came from three procedures, viz., rearrangement and rephrasing, elimination, and the addition of new material.[45] In writing of the convention Professor John A. Fairlie, himself a delegate, called it "the best and most representative assembly that has ever met in Michigan," and added that most of the delegates were "men of intelligence and training, and a good proportion of them were men of the first order of ability." [46] Of the ninety-six men so generously praised two thirds were trained in the law, at least twenty were businessmen, and seven were farmers. In 1850 a majority of the delegates were farmers.[47]

It would be both interesting and informative to analyze the numerous amendments proposed for each of the three constitutions of the state. There is space for only a brief summary. From 1835 to date (1942) 172 amendments have been proposed, of which 88 have been adopted and 84 rejected. Broken down by constitutional periods the distribution is as follows:

Constitution Making by the Amending Process

Period	*Proposed* [48]	*Adopted*	*Rejected*
1835–50	3	3	0
1850–1909	85	49	36
1909–42	84	36	48
	172	88	84

[44] *Address to the People, Submitting the Proposed Revision to the Present Constitution* (Lansing, 1908), pp. 3–4.

[45] For a summary of the new provisions and other data on the Constitution of 1909 see the writer's account, *op. cit.*, pp. 40–46.

[46] *Michigan Law Review*, VI, No. 7 (1908), 2.

[47] Data compiled from the *Manual of the Constitutional Convention of 1907* (Lansing, 1907), "Biographical Sketches," pp. 91–142. For a somewhat different occupational classification of these delegates see the Grand Rapids *Herald*, September 18, 1907.

[48] The proposal for Negro suffrage, defeated in 1850, is counted with amendments proposed under the second constitution.

Among the more important categories revealed by an examination of the texts of each of the proposed amendments to our present constitution are the following:[49]

SUBJECT MATTER OF PROPOSED AMENDMENTS

Categories	*Proposed*	*Adopted*	*Rejected*
Taxation and finance[50]	30	10	20
Suffrage and election	14	8	6
Changes of framework of government	7	4	3
Units of government	8	3	5
Eminent domain	5	2	3
Legislative apportionment	4	1	3
Liquor traffic	4	2	2
Compulsory attendance at public school	2	0	2

An apparent inconsistency on the part of the electorate is evidenced by an examination of the recent votes upon proposals for an increase in salary for members of the legislature. In 1926 the electors rejected by a decisive vote a proposal to increase the biennial salary from $800 to $1,200. Two years later an amendment proposing pay at the rate of $3.00 a day was adopted by a small margin, with the effect of awarding a much higher salary than had recently been rejected. This lack of consistency is explained by the fact that many voters thought that the daily wage was for the time spent in session only; they were much surprised to learn that they had sanctioned a remuneration of $2,190 for the biennium.

The present constitution stipulates that in 1926 and "in each sixteenth year thereafter" the question of "a general revision of the constitution" shall be submitted to the voters at the general election.[51] In compliance with this mandatory provision the electorate in 1942 decided by a narrow margin not to call a convention for constitutional revision.[52]

WESTERN MICHIGAN COLLEGE OF EDUCATION
KALAMAZOO, MICHIGAN

[49] Compiled from data in *Michigan Manual*, 1941, pp. 83–88.

[50] Including four income tax amendments between 1922 and 1936, all of which were defeated.

[51] Constitution of 1909, Art. XVII, Sec. 4.

[52] At least seven states require a vote at definite intervals on the question of calling a constitutional convention. In New Hampshire the period is seven years; in Iowa, ten years; and in Maryland, New Jersey, Ohio, and Oklahoma, twenty years.

LANGUAGE AND LITERATURE

PRESENT TENDENCIES IN FRENCH-CANADIAN NATIONALISTIC LITERATURE

ANTOINE J. JOBIN

IN ORDER to avoid any possible confusion of terms in this discussion of French-Canadian nationalistic literature, may I state at the outset that the word "nationalism," as employed so frequently in French Canada, has no political connotation, except in the minds of a negligible group of visionaries. In French Canada the exponents of a spirit of nationalism in thought, expression, and effective action are simply a group of intellectuals fully aware of the obvious fact that their language, culture, and civilization are on the defensive, beset by potent forces which may well succeed in overwhelming the "islet of Gallic culture in a vast Anglo-Saxon ocean." Precarious enough has been the position of this tiny minority for the last century and a half, but if we consider the probable effect of newly created agencies of communication upon the French-Canadian mind, we shall readily realize the magnitude of the problem facing intellectuals at the present moment. They admit, in fact, that the American radio, moving pictures, and pulp magazines may eventually Americanize the French province. Now, what the nationalists have in mind is the preservation within the Dominion of an ethnic group possessing a common origin, religion, language, and way of life.

Obviously, there can be no contradiction in the existence of an integral nationality within the State itself, since the British North America Act of 1867 recognizes a biethnic and bilingual régime which grants virtual autonomy to the provinces and admits, as well, of the existence of two ethnic groups on a basis of equality. In short, according to its Constitution, the Dominion of Canada cannot be exclusively Anglo-Canadian, though some of that group evidently think it should be. It may be affirmed parenthetically that the maintenance of a French civilization in the Dominion in no wise impairs the loyalty of French Canadians to Canada or to the Empire

as a whole. Cultural as well as political loyalties may exist and prosper side by side, as has been amply demonstrated in the numerous crises through which Canada has passed, notably those of 1776, 1812, and 1914, as well as the present one, in which the record of French Canada leaves nothing to be desired. I need not call to mind that in 1776 the only British North American colony which remained loyal to the Crown was the French-speaking one.

The aim and constant preoccupation of every French Canadian endowed with a heart and a brain of normal size is briefly stated by Abbé Lionel Groulx, professor of history at the University of Montreal: "Être français, rester français, c'est même plus que notre droit, c'est notre devoir et notre mission." [1]

To my mind, the enduring body of French-Canadian literature derives its primary inspiration from such a preconceived doctrine of nationalism, from an unswerving determination to produce useful literature which will contribute toward the preservation of the linguistic and cultural heritage. At the present time this laudable aim appears to be implemented by the consciousness of the need for a still more energetic effort now that the German blight has fallen upon France, which to Canadian intellectuals has ever been the source of light and idealism. Perhaps the same reason has induced American teachers of French to show an interest in Canadian culture and civilization after years of indifference.

In the purely literary genres most of the old familiar sources of inspiration still prevail, notably among better-known poets such as Blanche Lamontagne-Beauregard and Alfred Des Rochers; among essayists, or writers of brief sketches of French-Canadian rural life, such as Abbé Lionel Groulx, Adjutor Rivard, Georges Bouchard, and Frère Marie-Victorin; finally, even among the interesting group of contemporary novelists such as Ringuet, Savard, and Desrosiers. It is evident, however, that the treatment of regional themes by writers like Alfred Des Rochers and Rivard, for instance, marks a long step forward in a literature which, since the first World War, shows unmistakable signs of more mature thought, a keener sense of observation, superior craftsmanship, and a more realistic approach. Notable also in contemporary works is the absence of "la hantise de la France" — an obsession of so many authors during the formative period of this literature. This does not necessarily mean that

[1] *Directives* (Montreal: Éditions du Zodiaque, 1937), p. 63.

French Canadians have ceased to regard France as their mentor in matters intellectual, but it simply indicates a more completely Canadian cast of thought, as well as an assertion of French Canada's literary personality.

Lecturing on the various social and economic problems which have beset the French of America since the beginning of the great movement away from the land, Abbé Groulx inveighs against certain writers who should have reflected more on the essential social questions rather than devoted themselves to composing "little verses and insignificant prose." [2] In themselves, however, these compositions reveal, in their defense of an agrarian philosophy, the essential problem, namely, that the formerly sound rural economy of French Canada, the cornerstone of its racial and religious cohesion, has been undergoing a gradual transformation into a business and industrial economy. In 1931 only 36.9 per cent of the population remained on the land, as against the high figure of 85.7 in 1861. In other words, the majority of the French population, formerly independent and secure on their farms, and also far removed from foreign influences, are now crowding urban centers, where they are exposed to the precarious and automatic existence of the modern factory worker, as well as to various other obvious disintegrating forces.

In the light of these new conditions of life for the majority, it would seem that the hackneyed theme of country versus city might yield to descriptions of the fascinating and stimulating life of the conveyor line, or at least to depictions of the life of business. Yet the agrarian philosophy remains so firmly crystallized in the French-Canadian mind that the country theme persists in a considerable number of contemporary works, some of which, Ringuet's *30 Arpents*,[3] for instance, have been recognized outside the Dominion as possessing undeniable literary merit. Even Grignon's *Un Homme et son péché*,[4] a penetrating and convincing analysis of a miser's mentality, has as its setting a small rural settlement and, for secondary content value, the life of country people in Quebec.

This preoccupation with the soil on the part of so many writers has its origin in a didactic novel by Antoine Gérin-Lajoie, *Jean Rivard, le défricheur*, first published in 1862. It is perhaps the earliest of a long line of "useful" literary productions, and, in truth, it re-

[2] *Ibid.*, p. 83. [3] Paris: Flammarion, 1938.
[4] Montreal: Éditions du vieux Chêne, 1941.

sembles more a thesis than a novel, properly so-called. Foreseeing the inevitable overcrowding of the liberal professions, as well as the forced migration of thousands of his countrymen to the mill towns of New England unless some new fields of endeavor should be opened to them, Gérin-Lajoie urged young men to take up agriculture: "L'agriculture est la première source d'une richesse durable — elle est la mère de la prospérité nationale; la seule occupation réellement indépendante. Il n'y rien d'aussi solide que la richesse agricole." [5]

Since 1862 numerous authors have enlarged upon their precursor's thesis to inveigh against the drabness and insecurity of modern industrialism. Mindful of the depression years 1929–33, we must admit some force to their argument. Moreover, the old theme has been handled by certain writers — the poets Blanche Lamontagne-Beauregard and Alfred Des Rochers, the essayists Adjutor Rivard and Frère Marie-Victorin, the novelists Ringuet and Desrosiers — with infinitely more skill and art than it was by their predecessors. Far too many, on the other hand, have inclined toward an idealized picture of life on the farm in the good old days. Americans will recall that we also had our period of saccharine "Pollyanna" literature prior to the first World War.

In passing, a curious fact may be noted: several authors who persist in their rejection of urban life in all its phases dwell in the city and apparently like it. Adjutor Rivard is a municipal judge; Mgr. Camille Roy is the head of Laval University; Abbé Lionel Groulx is professor of history at the University of Montreal; Blanche Lamontagne-Beauregard, the poetess of La Gaspésie, has lived in Montreal most of the time since her marriage; finally, Ringuet is an oculist. Despite the fact that one remains unconvinced that the writers themselves entertain any particular predilection for country life, the motivation for their expressed attitude lies in their common belief that flight from the land is prejudicial to the cause of racial cohesion and also to the traditional virtues of their people.

To Adjutor Rivard, for instance, only unhappiness and vain regret lie in store for those who abandon their native soil. In addition, such desertion has more serious implications, since it means surrender to the very forces which may eventually achieve complete disintegration and dispersion of the ethnic unit. Like many of his colleagues, M. Rivard urges young men to avoid the lure of the city,

[5] *Jean Rivard, le défricheur* (Montreal, 1918), p. 19.

where it is likely that they will lose their language, religion, and racial identity:

> Ceux qui partent ainsi savent-ils bien ce qu'ils font, et qu'ils désertent un poste d'honneur, et qu'ils manquent à un devoir sacré? Croient-ils ne laisser derrière eux qu'un toit sur quatre murs?
>
> Ce qu'ils quittent, en vérité, et à quoi ils renoncent, c'est plus que cela: c'est le pays natal; pour celui-ci c'est la montagne, pour celui-là c'est la plaine, mais pour tous au flanc des collines ou dans la vallée, c'est la paroisse où s'écoula, paisible, la vie des anciens, l'église où se plièrent leurs genoux, la terre qui garde leurs os; c'est la glèbe que les aïeux féconderent d'un rude et pénible labeur; c'est le trésor des traditions familiales, les saintes coutumes du foyer, le culte du passé, la religion du souvenir; et c'est peut-être aussi le parler des ancêtres, hélas! et le respect de leurs croyances . . . c'est tout le patrimoine ancestral qu'ils abandonnent, c'est la patrie qu'ils désertent! [6]

M. Rivard, as well as the majority of his fellow regionalists, categorically rejects the idea of modern progress as it is proclaimed in the United States. Progress in the American sense represents a great force working toward the disruption of the whole scheme of life of French Canadians and of the culture which they cherish. We recall that precisely the same point of view inspired Georges Duhamel to write *Scènes de la vie future.*[7]

While we may readily grant that overemphasis of the country theme stems from the peculiar, and extremely precarious, position of a small French minority in North America, it is also likely that heredity accounts in part for such an *idée fixe.* Intense dislike for the turmoil and complexities of life in a modern city might be expected from the descendants of the pathfinders of a continent, the *coureurs-des-bois,* clearers of forests and tillers of the soil. Seventeen years before Gérin-Lajoie published his propaganda treatise, Thoreau had taken refuge on the shore of Lake Walden because he could not put up with the noise and the artificial life of Concord! Country versus city; Montreal, Three Rivers, Detroit, and Pittsburgh versus the wholesome and independent life of one's own domain; screwing the same nut in the same way on the same sort of mechanism belonging to somebody else versus the tasks of the husbandman, tasks which are varied and require individual initiative, ingenuity, and resourcefulness — such is the thought that underlies the writings of the many French Canadians who abhor standardization and industrial regimentation of the individual.

[6] *Chez nous, chez nos gens* (Montreal: Action française, 1924), pp. 42–44.
[7] Paris: Fayard, 1938.

Substantially the same thought appears over and over in Ringuet's *30 Arpents*, a true and convincing novel of farm life in Quebec. Here again, despite the realism of the portraits which depict the habitant as a normal human being — a kinsman, in fact, of de Maupassant's Norman peasants — instead of as the saint of so many regional works, the farmer represents the faithful guardian of the language, traditions, and religious faith of a people. "Les habitants sont les vrais Canadiens,"[8] says M. Ringuet. To him also it is a crime to abandon the soil. "Lâcher la terre c'est comme mal tourner."[8] The author substantiates his thesis in favor of country life by depicting the precarious existence of Franco-American workers in an American manufacturing town. Referring to the great depression, the hero, Euchariste Moisan, states that it wouldn't make any difference in French Canada whether factories should cease operations or not, because there are so few of them.[9] This, of course, is a false assumption, which ignores the fact that only a minority of French Canadians live on the land. Yet it does reveal to what extent the city worker remains a truly forgotten man among the creative writers. I need not add that this is not true of the articles and books of publicists, sociologists, and economists, whose mounting interest in the growing army of the proletariat is as deep as it is sincere.

Throughout *30 Arpents* the reader will not fail to note the author's emphatic repudiation of the twentieth-century idea of progress, which he regards as utterly false in its conception of values contributing to the good life. Like many of his predecessors, notably Blanche Lamontagne-Beauregard, Georges Bouchard, and Frère Marie-Victorin, M. Ringuet resents the encroachment of industrialism, the destroyer of the picturesque in life as well as of the individual personality. Mechanical progress and the mass-production system do not constitute real progress in terms of human happiness and contentment. During the depression a false concept was dispelled from the minds of many who had succumbed to the lure of an easy life:

> Toute la crise actuelle n'était-elle pas le plus beau démenti à cette fausse et dangereuse idée du progrès? Pour lui, Euchariste, la voie était claire: ce qui s'imposait, c'était le retour au mode sain d'autrefois; renoncer aux mécaniques et vivre sur les trente arpents de terre en ne leur demandant que ce qu'ils pouvaient donner.[10]

[8] *Op. cit.*, p. 127. [9] *Ibid.*, p. 286. [10] *Ibid.*, p. 287.

I note also an intense spirit of nationalism in a novel that has attracted considerable attention among Canadians and Franco-Americans, *Menaud-Maître-Draveur*,[11] by Abbé Félix-Antoine Savard. In addition to presenting an absorbing and dramatic narration of the perilous life of woodsmen in the forests of Quebec, a story interlarded with racy dialogue, Abbé Savard stresses the manner in which his countrymen surrender their independence when they consent to work for the Anglo-Canadians or Americans in the lumber camps or pulp mills. On the farm, he believes, the "Canadien" is king; away from it, he becomes a slave. Every French Canadian should possess his own domain and remain there in the environment suitable to his peculiar aptitudes and temperament. One senses in this novel the author's humiliation that his countrymen, the discoverers, explorers, and first settlers of Canada, should be engaged in backbreaking toil for foreign employers. He berates as thoughtless fools and cowardly knaves those who abandon the patrimony bequeathed by their ancestors.

We have noted that the problem of survival remains an *idée fixe* in the minds of most contemporary authors in purely literary genres. It is not within the purview of this brief paper to discuss the considerable number of intellectuals who are attacking directly and objectively, as well as creatively, the social and economic problems of their province. In view of the intrinsic quality as well as the timeliness of these thought-provoking works, however, one cannot overlook such contributions to French-Canadian intellectual life.

The present trend in the writings of three outstanding leaders, Abbé Lionel Groulx, M. Edouard Montpetit, and M. Hermas Bastien, points toward an adaptation to the *fait accompli*. M. Edouard Montpetit, noted economist and general secretary of the University of Montreal, has for years been urging young men to take an active part in the business, financial, and industrial life of French Canada. The French of Canada must rid themselves of the outmoded idea that participation in the productive fields of activity will hamper the full development of their intellectual life. If control of commerce and industry, together with the greater part of the natural resources of Quebec, now rests in the hands of an oligarchy of Anglo-Canadian and American financiers, it is the fault of the elite, who have neglected business and industry for the overcrowded liberal professions.

[11] Quebec: Librairie Garneau, 1937.

Abbé Groulx recommends a revamping of the educational system, which, according to him, bears a large share of the responsibility for the present plight of the French population. It is the duty of educators to instill, first of all, a French-Canadian ideology in the minds of their pupils, an ideology which would have as its basic points: "1. La conscience d'être français. 2. La fierté de l'être. 3. La volonté de le rester."[12]

Americans who believe that Catholic leaders in Canada are fascist in their mental attitudes might derive considerable enlightenment from two collections of public lectures by Abbé Groulx, *Directives* and *Orientations*.[13] According to M. Groulx, a small group of selfish capitalists compose a financial and industrial oligarchy which imposes its will not only upon the helpless masses, but also upon the weak-kneed politicians. He calls upon his people to shake off the yoke of oppression and to emancipate themselves from a handful of exploiters. Conquest of the land of Quebec to its extreme limits must of necessity include conquest of the natural resources for the benefit of the majority, not for the enrichment of the few, as at present.[14]

Abbé Groulx recommends a cessation of the flow of population away from the agricultural classes to the growing industrial proletariat, but he does not say just how this may be accomplished, except by extending the area of colonization. He does succeed, however, in awakening young men to the realities of the situation and points out to them that their fate lies in their collective will to effective action. Intellectual and spiritual rearmament of the masses seems to be M. Groulx's chief aim.

M. Hermas Bastien also demands immediate restraints upon the plutocracy and the formulation of a clearly defined agrarian policy by the government, with a view to restoring the balance between farmers and factory workers. In lieu of a few large industries controlled by a small group of powerful interests, he would have a large number of small units offering opportunities for the utilization of all the skills and aptitudes. Conscious of the penetration of new mental attitudes, of the gradual Americanization of the French-Canadian mind through the agencies of radio, motion pictures, and pulp magazines, M. Bastien believes that nationalistic education of the

[12] *Directives*, p. 96.
[13] Montreal: Éditions du Zodiaque, 1935.
[14] *Directives*, p. 230.

masses is imperative if the people are to retain their French characteristics and mentality: "Refrancisons! Il faut refranciser l'âme. Il faut une éducation nationale. Que les écoliers prennent conscience de leur histoire, de la situation précaire de leur destin ethnique, de leur devoir de survivre." [15]

Summing up briefly this cursory discussion of trends in contemporary French-Canadian literature, I should point out the following tendencies as important:

1. Coincident with the marked improvement in form and content, a more militant spirit seems evident in the literary genres. Ringuet and Savard may be cited as examples of this tendency. The causes are obvious.
2. Of the familiar regional themes, it is curious to note the persistence of the conflict between city and country, despite the fact that the former has gained the ascendancy in French-Canadian life. Again obvious causes may be adduced to explain this mental attitude. A more mature and realistic treatment of the country theme is apparent in works of unmistakable artistic merit. The day of "l'heure des vaches" and "l'adieu à la jument grise" is past, although poets and essayists still tend to idealize life on the farm. Owing to conditions peculiar to French Canada, an agrarian philosophy will undoubtedly continue to claim the attention of writers.
3. Long regarded as a negligible quantity, as compared with historical and poetical works, the novel appears to have attained maturity in French Canada. Léo-Paul Desrosiers' historical novels and Claude Grignon's penetrating psychological novel, *Un Homme et son péché* may be ranked with the best novels on our own side of the border, in addition to the works of Ringuet and Savard cited above.
4. If precedents may be trusted, the spirit of nationalism is likely to become more intense in proportion as the impact of foreign penetration and influence makes itself felt in Canada. Many contemporary works are merely regional in tone and content; it is in sociological, economic, and political studies that a militant spirit of nationalism prevails. This literature may claim our interest for its wealth of ideas and its intense francophile spirit, as well as for its "esprit frondeur," a French characteristic that the art forms lack.

[15] *Conditions de notre destin national* (Montreal: Éditions Albert Lévesque, 1935), p. 177.

5. Finally, I note unmistakable evidence of a quickening of intellectual activity in French Canada, a far greater interest in ideas and discussion, and a marked tendency toward a true representation of life and a realistic portrayal of character. In short, French-Canadian literature has taken a long step forward, such as has been noticeable in American literature since the first World War.

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THE CONDE DE MATISIO AND ROBERT THE DEVIL

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IN THE history of Spanish literature the name of the seventeenth-century author Juan de Zabaleta is generally associated either with the drama or with two volumes of satirical essays. His contribution to the theater is almost entirely that of a collaborator, but, to be sure, a collaborator of the greatest dramatists of his time. His more enduring reputation, however, rests solidly on his essays, called *El día de fiesta por la mañana*, 1654, and *El día de fiesta por la tarde*, 1660. These clever sketches of types and customs in Madrid have served to illuminate many obscurities in seventeenth-century plays, especially in regard to details of costume.

Competent editions of his *Días* have been prepared,[1] but Zabaleta's earlier work, the *Vida del conde de Matisio*, has received scant attention. This long short-story relates the deplorable history of the French count Ludovico, el conde de Matisio, and paints a merciless portrait of a man devoid of every virtue. This typical antihero properly belongs in the realm of the picaresque, and as such was treated briefly by Dr. Frank W. Chandler in his *Romances of Roguery*[2] and his *Literature of Roguery*.[3] Chandler commented that in "*The Conde de Matisio*, written during the decadence of the picaresque novel in Spain,"[4] Ludovico "was no longer a *pícaro* but an out-and-out villain."[5]

Chandler was the first to point out the resemblance between the character of Ludovico and that of Robert the Devil in his statement

[1] Dr. G. L. Doty has edited both: *El día de fiesta por la mañana*, in *Rom. Forsch.*, 41 (1928): 147–400; *El día de fiesta por la tarde*, in *Gesell. für rom. Lit.*, Band 50. Jena, 1938.

[2] *The Picaresque Novel in Spain*, Part I. New York: The Macmillan Co., 1899.

[3] Two vols. Boston and New York: Houghton Mifflin Co., 1907.

[4] *Literature of Roguery*, p. 197.

[5] *Ibid.*, p. 14.

that "Juan de Zabaleta . . . did not attempt in his *Vida del conde de Matisio* of 1652 satiric observation, but turned to writing a novel, the hero of which was a sort of Robert the Devil." [6] This comparison ever since that time has gone unconfirmed, except for the corroborative words of Menéndez y Pelayo, that Robert the Devil "no sólo penetró en nuestro teatro sino que en el siglo XVII recibió nueva forma novelesca en *el conde de Matisio*, de D. Juan de Zabaleta." [7] It is the purpose of this study to examine that relationship and to show to what extent it is superficial.

The Robert the Devil story was known in Spain a great many years before the publication of the *Conde de Matisio* in 1652. Probably the earliest reference to that story is to be found in *El libro del Cauallero Zifar*,[8] in which he is called "Alberto Diablo." This is clearly a confusion of the names of Robert and his father Aubert, as Menéndez y Pelayo recognizes.[9] Later, Robert is mentioned in *El conde Lucanor* [10] and *El alcaide de sí mismo*,[11] two plays written by Zabaleta's most eminent collaborator, Calderón de la Barca. In each of these allusion is made to him, without elaboration or explanation, as the hero of a well-known legend.

There can be little doubt that by 1652 everyone must have been familiar with Robert through numerous editions of the popular chapbook *La espantosa y marauillosa vida de Roberto el Diablo, hijo del Duque de Normandia, el qual despues por su sancta vida fue llamado hombre de Dios*.[12] The oldest Spanish edition on record is that of Burgos, 1509, which formerly belonged to the library of the son of Christopher Columbus.[13] If Zabaleta, a Dominican, did not know of the Robert story from any of these sources, he may well have seen

[6] *Romances of Roguery*, p. 385.

[7] *Orígenes de la novela* (Madrid: Bailly-Bailliere, 1925), I: cxlvi.

[8] Edition by C. P. Wagner, p. 242. Ann Arbor: University of Michigan, 1929. Dr. Wagner dates this work about the year 1300.

[9] *Orígenes*, I: clxxxi.

[10] *Biblioteca de autores españoles*, 12: 438B: "Un Roberto, que Roberto/Es el diablo para mí." H. W. Hilborn, in *A Chronology of the Plays of D. Pedro Calderón de la Barca* (Toronto: University of Toronto Press, 1938), p. 62, dates this play *c.* 1650–51.

[11] *Biblioteca de autores españoles*, 9: 519A: "¿Y sos Roberto/El diabro?" Hilborn, *op. cit.*, p. 34, dates this play 1636.

[12] Editions of 1509, 1530, 1558, 1582, 1588, etc.

[13] "Registrum" of Fernando Colón, a manuscript in Seville. A. M. Huntington has reproduced this manuscript in facsimile: *Catalogue of the Library of Fernando Colón*. New York, 1905.

it in a French chapbook,[14] or in the Latin version of another Dominican, Étienne de Bourbon.[15] In any case, wherever he may have met the story, Zabaleta could scarcely have been ignorant of Robert the Devil. To what extent he may have used it or adapted it will be seen from a comparison of the two stories.

The following summary will relate the melodramatic life of the Conde de Matisio, omitting the interminable preaching that mars the original:

The Conde de Matisio had an only son named Ludovico, for whom he sought a tutor when the boy was seven years old. This tutor he chose carefully, and although it is a bit outside the subject, it might be of professional interest to note some of the father's reasoning.

There were numerous candidates for this position because "there are many poor men of great ability and long study, people so unhappy that, in order to live ten years in comfort, they spend fifty in studying and dying." Among them was one very brilliant student, but the Count would not accept him because too brilliant a student makes an impatient teacher, and an important thing in teaching is praise, and how can a brilliant teacher praise what irritates him! He finally chose Guillermo, a rhetoric professor from the University of Paris, because he made clear simple explanations and patiently answered all questions.

The father also gave his son two servants, the clever, unscrupulous Leonardo, and the intelligent, philosophical Mauricio. As soon as the teaching began Ludovico showed himself exceptionally stupid, and ready to listen only to the subversive counsels of Leonardo.

At seventeen Ludovico displayed only bad qualities and was the despair of his father. One day from his room issued shouts of laughter. When the Count investigated, he learned that his son was amusing himself by having the barber pull teeth from a peasant, who received a doubloon in compensation for each tooth extracted. The following morning the discouraged father was taken sick with a fever that was to prove fatal, but before dying he gave Ludovico a long salutary lecture, vainly hoping that the solemnity of the occasion might make an impression on his son.

Now with the death of the old count, Ludovico has become the Conde de Matisio and master of a fortune, though still under the influence of Leonardo, the wicked page. All the servants were dismissed except two, Guillermo and Mauricio: the former because he had a beautiful daughter, Teodora, whom Ludovico found attractive;

[14] Editions of 1496, 1497, *c.* 1520, 1545, *c.* 1550, etc.

[15] In Lecoy de la Marche, *Anecdotes historiques, légendes et apologues tirés du recueil inédit d'Étienne de Bourbon, dominicain du XIII^e siècle.* Paris, 1877.

and the latter because he had been tactful enough not to antagonize Leonardo.

Before leaving with Leonardo for a trip to Paris, where he was to become a man of the world, Ludovico confessed to Leonardo his love for Teodora and begged him to approach her with promises in return for her favors. Leonardo did this with great misgivings because he knew her to be a thoroughly good woman. Being promptly rebuffed, just as he had expected, he lied to Ludovico, saying that Teodora would be agreeable to his advances provided she were first furnished with a husband. This husband was Mauricio, with whom Teodora was in love.

Since at the betrothal of Teodora and Mauricio he had been very generous in gifts and entertainment and since he had spent money freely during his trip to Paris Ludovico soon began to feel a little pinched. To remedy his lack of funds he induced some men to help him break into the church, and there he forced a priest to reveal the treasure to him. He committed all sorts of sacrilegious acts during the robbery.

The next day the wedding took place, and Ludovico sent Teodora a fine ring, which she tactfully refused, suspecting that it had come from the church robbery. Yet, in spite of that refusal, he felt that the way was smoothed for his advances; and so, having sent Mauricio away on a trumped-up errand, Ludovico presented himself and, quoting Leonardo's reported message, asked her favor. She told him that Leonardo had lied, and sent him off furious against Leonardo. When the latter returned, Ludovico killed him, and had him buried in the garden. Then he kidnaped Teodora, taking her husband along since he refused to be separated from his wife.

As they entered the house on Ludovico's country estate Mauricio dropped to his knees and prayed to God for help. Then they all went in to a fine banquet that was awaiting them. During the meal, while all but Teodora and Mauricio were eating, suddenly Ludovico raised his eyes in terror and ran out as though he were being summoned. When they all rushed out to see what was going on, they beheld Ludovico standing on the spot where Mauricio had prayed, suddenly carried off by a frightful black cloud, presumably to appear before God's throne for judgment. Ludovico's accomplices fled, while Mauricio, Teodora, and her father rode slowly back to Matisio.

This summary is evidence that Zabaleta was familiar with the violent love crimes of the Italian *novelle*, although none of the well-known writers of Italy seems to have written this particular tale. The final dramatic scene of poetic justice stems, however, from a quite different source, and from one that a Dominican might more properly have known. This is the miracle, in which a favorite dénouement

shows the innocent victim saved because of his devotion to the Virgin.

It is, of course, the character of Ludovico that suggested to Chandler the comparison with Robert the Devil, because Robert also is thoroughly bad, passing from one crime to another, with respect for neither man nor God. That this is a superficial reason for calling Ludovico "a sort of Robert the Devil" can be proved by a short résumé of the Robert story up until the time of the conversion. Since there is no redeeming quality in Zabaleta's antihero, whatever parallels there may be will appear in the following summary of the first part of Robert's life.

The Duke of Normandy was an ideal ruler and a God-fearing man. After marrying to please his people, his great sorrow was the fact that his wife did not bear him a son. After seeing their prayers to God go unanswered for sixteen years, the Duchess in a fit of devil-inspired temper said,[16] "May I have a child even though it be the Devil!" Her son Robert was born in a frightful display of thunder, lightning, and wind, and almost at once began to reveal his supernatural character. He was unusually strong and handsome, and at one year walked and talked like a five-year-old. He used to maltreat his young companions, playfully breaking their arms or legs, so that the minute they caught sight of him, they all fled, shouting "Here comes Robert the Devil!"

When Robert was six or seven his father secured a teacher for him, but Robert promptly killed him because he wanted to correct Robert's evil ways. In church he threw dust or refuse in the mouths of priests who wished to sing, and struck the kneeling worshipers, so that they fell on their faces. His mother suggested that making him a knight might change his disposition and manners, but Robert only became worse thereafter. He used to go about violating maidens, beating and robbing men, and plundering churches incessantly. There was not one abbey in the country around Rouen that he did not pillage and destroy.

Robert put out the eyes of messengers and knights whom his father sent out after him, and told them that without eyes they would sleep much better. Furious because of a county-wide proclamation to capture him at all cost, Robert gathered together all the worst young men in Normandy, built a stronghold in a wood, and proceeded to prey on everyone. They cut throats, raped women, murdered merchants, killed poor pilgrims, and in every way showed themselves true wolves, ravishing and devouring all they met.

One day Robert was delighted to encounter seven ancient her-

[16] "Concibiesse yo y fuesse el diablo." Edition of Salamanca, 1605, fol. A3v.

mits, whom he slew in despite of God and the Holy Church. Immediately afterward, having learned that his mother was at the Castle of Arques, he set off to see her. Still wearing his bloodstained clothing and grasping his dripping sword unsheathed, he begged her to tell him why people disliked him, and why he was so cruel. She, thinking her last day had surely come, threw herself at his feet, entreating his pardon for having given him to the Devil even before he was conceived, and urged him to kill her.

Robert was stunned by this information, at the same time being greatly relieved that the responsibility was not entirely his. At once he set out for Rome to beg the Pope to hear his confession, since no one less than the Pope could possibly forgive sins of such magnitude. On the way he stopped at his stronghold to try humbly to persuade his wicked companions to give up their evil ways and confess their sins, but they refused angrily to listen to such strange doctrine from their former leader. Their stubborn determination to continue the same evil life made Robert so angry that he locked the door and killed every last one of them. Then he made the sign of the cross and rode off through the forest toward Rome and seven years of extreme penance.

This summary presents only a partial picture of Robert, because with his departure for Rome the Devil story becomes the Saint story. Thus it is that in these two parts Robert exemplifies the frightful figure of a blasphemer and scourge of the church, who by an even more striking penance comes later to be regarded as a saint, just as did Mary of Egypt and others whose saintly lives shine all the more brightly by contrast with their early sins. Robert has the additional hagiographic touch in that, like St. Alexis, he lives unrecognized under the porch steps in Rome, and associates with the dogs.

Between the first part of the Robert story and that of the Conde de Matisio there are clear parallels that could not be the result of coincidence. One is that in both stories the protagonist is thoroughly wicked and an enemy of law, virtue, and the church. Another is that both Robert and Ludovico have noble, God-fearing fathers, wh gave their sons teachers at the age of seven. The age of seventeen also marked a definite change or phase in the life of each: for Robert it meant a clean break with his home and parents, after his knighting; for Ludovico it fixed the time of his freedom from all parental restraint through the sudden death of his brokenhearted father.[17]

[17] Chandler, *Romances of Roguery*, p. 109, comments that Ludovico's "father is hastened off like the man who ordered his epitaph to be *los muchos médicos me mataron.*"

These parallels indicate that Zabaleta not only knew the Robert story, but also had it fairly well in mind when he wrote the *Conde de Matisio*. It does not, however, justify the German scholar Pfandl in saying that Zabaleta "en la *Historia y Vida del conde Matisio* (1652) imita, en forma novelesca . . . la terrorífica leyenda de Roberto el Diablo . . ., es decir, que se sirve de la historia de aquel criminal, siguiéndola paso a paso. . . ." [18] That statement is true only to the extent that Robert and Ludovico were both monsters of vice and enemies of the church. Beyond that common characteristic and the two significant years of seven and seventeen in their lives, the wide differences between them are more striking than these parallels. Ludovico is weak and cowardly, addicted to gambling and petty crime, the dupe of cheats and fortunetellers. Only late in the story, when he rises in well-justified wrath and kills the lying Leonardo, does he attain the stature of a criminal worthy of respect. After that murder he proceeds with commendable dispatch to the kidnaping of Teodora, and even manages to derive a certain vicarious dignity from the awesomeness of his death. Yet in spite of his noble end, as a figure he remains small and mean, a ready tool of cleverer scoundrels, in short, a vicious weakling rather than a robust criminal.

Robert, on the other hand, is a strong, dramatic figure who carves out his own life, both the bad and the good. He, of course, is the *Wunschkind* of folklore, the result of his mother's unfortunate appeal to the Devil: therefore Robert is destined to inherit the "devilish" characteristics of his supernatural sire. That heritage explains why Robert is so cruel to the church, to churchmen, and to virtue wherever found; and may also account for the lusty vigor of his career of crime. Like a Miltonian Lucifer in reverse, Robert, or Lucifer, *fils*, also gains some measure of grandeur in his hellish exploits. But at the same time Robert as a potential saint cannot understand his own wickedness, and feels that there must be some explanation of such a bent toward violence with never a single desire to do a kind act. This is borne in upon him as he is riding toward the Castle of Arques by the shock of seeing people avoid him.

"Fair Sire God of Paradise," he cries, "how is it that everyone flees in such a way before me? Now I am indeed unhappy and accursed, and the most unfortunate of men in the world. . . . Now I

[18] Pfandl, Ludwig, *Historia de la literatura nacional española en la edad de oro* (Barcelona, 1933), p. 386.

ought surely to hate my wicked life because I believe indeed that I am hated by God and the world." [19]

Such a seemingly naïve reaction could come only from a man who truly believed that he was driven by a devil within; and only because of such motivation could the reader accept that remark and be prepared for Robert's sudden conversion. Robert begs his mother to tell him that either she or his father is to blame for his wickedness, because if the responsibility lies outside himself there is some hope of his gaining forgiveness for his sins. This attitude reveals the seldom-recognized basic motivation of the Robert story, which is that the true mainspring of the whole action is the desperate offer of the Duchess, the tragic consequences of which are visited on her devil-ridden son.

Considered in this light, Robert is the unwilling instrument of the Devil's vengeance upon his greatest enemy, the Christian Church and Christian virtue. It is a curious case of a compact with the Devil in which the contracting party, who is the Duchess, remains a passive figure, once her wish is granted. Unquestionably she suffers torture in her mother love, but it is her son who is the active agent and hence the repentant sinner under moral obligation to do the penance. It is a story calculated to capture the imagination of the people; and clear evidence of its success is the great number of editions in French, Spanish, English, and other languages.

It is small wonder that Ludovico, when compared with such a marked personality, pales into insignificance and is forgotten, since the only element of interest in his story is to bring an enemy of the people to his just deserts. Beyond that, Ludovico is neither a symbol of evil nor a criminal on a grand scale nor a future saint driven mad by a devil within. Robert, who is this symbol as well as the criminal and future saint, might therefore be well justified in resenting hearing Ludovico described as "a sort of Robert the Devil."

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[19] "Beau sire dieu de paradis a quoy tient il que chescun fouyt en telle maniere deuant moy. Or suys ie bien mal heureux et mauldit et le plus mal fortune homme du monde. . . . Or doy ie bien haye ma meschante vie car ie croy bien que ie suys hay de dieu et du monde." — *La vie du terrible Robert le dyable.* Lyon, 1496, fol. 9.

MEDICAL SCIENCE

ANURIA AS PRODUCED BY THE TOXIC ACTION OF SULFAPYRIDINE ON THE KIDNEYS: A CASE REPORT

RAYMOND W. MONTO

SINCE the introduction of sulfapyridine kidney complications have acquired a prominent position in connection with sulfonamide therapy. Renal damage from sulfanilamide has been reported only after severe hemolytic anemias, with resulting deposition of the débris in the kidney (3). Sulfapyridine characteristically initiates renal insufficiency by plugging both ureters with drug calculi, with production of an "extrarenal" or obstructive anuria. The kidneys may suffer severe damage to the renal tissue because of back pressure unless the obstruction is removed immediately.

The first reports of kidney complications in sulfapyridine therapy in man were made by Southworth and Cooke (2). They found crystalluria, hematuria, albuminuria, renal colic, and anuria, with subsequent azotemia. Since then there have been numerous case reports of anuria resulting from mechanical blocking of the ureters by the drug calculi.

It is the purpose of this paper to present a case in which anuria was produced by direct toxic action of the sulfapyridine upon the kidney so as to cause an "intrarenal" type of anuria.

CASE REPORT

The patient, a 55-year-old female, entered the Henry Ford Hospital complaining of nausea and vomiting of four days' duration. The past history was not unusual.

Examination revealed the temperature to be 102° F., pulse 120, and respirations 28. The patient was markedly dehydrated, and the nares were seen to dilate with movements of respirations. The remainder of the abnormal findings was limited to the chest. A loud friction rub was heard in the left axilla. The percussion note was impaired at the left base, with suppression of breath sounds and

many crepitant râles in the same area. The blood pressure was 160/75.

Initial laboratory investigation of the blood revealed hemoglobin to be 8.6 gm., red cell count 3,390,000, white cell count 20,650, with 85 per cent polymorphonuclear cells. The urinalysis gave a specific gravity of 1.008, acid reaction, albumin 3 plus, sugar negative, benzidine test negative, and, microscopically, many pus cells and occasional red blood cells. Routine examination of the stool showed nothing unusual. The Kline exclusion test for syphilis was negative. Blood chemistry was as follows: nonprotein nitrogen, 66.6 mgm. per cent; carbon dioxide combining power, 45.7 vols. per cent; sugar, 88 mgm. per cent; chlorides, 440 mgm. per cent. Stereoscopic X-ray examination of the chest gave evidence of a central pneumonia in the left lower lobe. On direct examination the sputum was found to contain many type III pneumococci.

The initial treatment was symptomatic with adequate administration of fluids, including blood transfusions for two days. On the third hospital day sulfapyridine therapy was instituted; the patient was given an initial dose of two grams and one gram every four hours thereafter. Respirations became more rapid, and the patient was placed in an oxygen tent.

On the fifth hospital day and after a total ingestion of nine grams of sulfapyridine the urinary output dropped suddenly to 75 c.c. in 24 hours. Urinalysis revealed the specific gravity to be 1.009, acid reaction, albumin 4 plus, sugar negative, benzidine test positive for blood, and, microscopically, many red blood cells, white blood cells, and granular casts. The patient's general condition rapidly became worse; a spread of the pneumonia and evidence of myocardial failure were noted. Stupor appeared, and loss of bladder control rendered it impossible to make accurate measurements of urinary output.

An electrocardiogram yielded no cause for comment, and the patient was digitalized. The nonprotein nitrogen of the blood became elevated, and a steady increase in blood pressure to 210/150 was observed two days before death. Urine culture six days after anuria produced a growth of Bacterium coli. A steady downhill course terminated on the patient's tenth hospital day, at which time her temperature had reached 105° F. Permission to make an autopsy was obtained.

AUTOPSY REPORT

At necropsy lobar pneumonia of the right upper and of the left lower lobes was found, as well as fibrinous pleurisy and pericarditis. Type III penumococci were cultured from the lungs.

The chief interest centered about the kidneys. The left kidney weighed 200 grams. The capsule stripped readily, revealing a granular cortical surface. Numerous punctate hemorrhages were present over the cortical surface, which presented a mottled yellowish gray and red color. In sagittal section the cortex showed some fine scarring, with an average thickness of five centimeters. The pyramids were normal, as were the renal pelves. The right kidney had the same general appearance as the left. There was no evidence of ureteral obstruction.

Microscopic sections of the kidneys revealed marked degenerative changes and necrosis, confined largely to the convoluted tubules of the cortex. These changes ranged from mild cloudy swelling to complete necrosis and were found diffusely through the kidney cortex. A few atrophied and hyalinized glomeruli were seen. Many of the remainder of the glomeruli were acutely congested. The renal arterioles showed thickening of their walls. Plate I illustrates the changes in the kidney cortex.

COMMENT

Though it has been postulated that renal damage and anuria may be produced by the toxic action of sulfapyridine on the kidneys, it has not been reported in man in the literature. Rake, Van Dyke, and Corwin (1), in their experiments on the laboratory animals which were given prolonged doses of sulfapyridine, were able to produce the type of kidney changes that have been described in the case presented.

The sulfonamide drugs are toxic materials and are eliminated by the kidneys in a manner similar to that of other renal irritants. The development of the renal insufficiency depends upon a number of factors, but primarily upon the presence of previous kidney damage. It is well known that complications referable to the urinary tract are more frequent in individuals suffering chronic renal disease. Such organs have a lower reserve, and hence are more likely to fail when added work is encountered. It is noted that the case reported gave

evidence of renal damage in that the initial urinalysis revealed a marked albuminuria, with an elevation of blood pressure.

The mechanism for the production of the usual type of sulfapyridine anuria, that is, obstruction of both ureters with calculi, is unknown. The calculi have been found to consist of a large percentage of acetylated sulfapyridine. On the basis that this compound is more soluble in alkaline solution, it has been advocated that patients receiving this drug be given alkalies. Clinical experience has shown this to be of doubtful value. Calculi have been reported in cases in which urines have been consistently alkaline in reaction.

SUMMARY

A case is reported in which sulfapyridine produced anuria by causing an acute toxic nephritis, with principal changes in the convoluted tubules. The patient developed a severe hypertension terminally.

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Photomicrograph of the kidney cortex, showing marked degenerative changes and necrosis in the convoluted tubules. The glomerulus is acutely congested

RECENT STUDIES ON THE EPIDEMIOLOGY OF TULAREMIA

JOSEPH H. SHAFFER

THE disease known as tularemia was first recognized as a clinical entity through the work of McCoy and Chapin in 1912 (2) on the etiology of a plaguelike disease occurring among rodents in Tulare County, California. They isolated the causative organism, established its bacteriological and cultural characteristics, and named it "tularense" for Tulare County.

Since 1912 this organism has been identified with illness in human beings in every state in the Union. It has been recognized in ten foreign countries since 1925. The public health problem associated with it is seen as one of increasing importance when we consider its prevalence. There were 2,088 cases of tularemia, with 139 deaths, reported for the year 1938; this figure was increased to 2,200, with approximately 150 deaths, for the year 1939 (5).

It is now known that, in addition to affecting the rabbit, Bacterium tularense may cause disease in many other forms of American wildlife. Human illness has been traced to contacts with the wild rabbit, fox, coyote, raccoon, squirrel, woodchuck, skunk, meadow mouse, rat, muskrat, beaver, pheasant, horned owl, sheep, lamb, hog, and dog, to fish, and to wood tick, biting flies, and other insects.

Water-borne infection, presumably from contamination with infected animals, has been reported. Positive cultures of B. tularense were reported in samples of water taken from Montana streams, according to information published by workers at the Rocky Mountain Laboratory of the Public Health Service at Hamilton, Montana (4).

Recently we became interested in a house pet, namely, the domestic cat, as a factor in the spread of tularemia to human beings. Thorough study of the three following cases points to infection as having been incurred from such a source.

CASE 1

An optometrist, a white male, age 50, was admitted to the Henry Ford Hospital after having been ill at home two weeks with headache, shaking chills, muscle pains, fever, and an irritating nonproductive cough, attended by a feeling of tightness in the chest. Three weeks before admission an itching pustular lesion had appeared on the dorsum of his left hand. He noticed swelling and a tenderness of the left epitrochlear and axillary lymph nodes. Our studies of the patient's blood disclosed a mild secondary anemia. The leucocyte count was 5,350, with 70 per cent polymorphonuclear cells. The blood sedimentation rate was 28 mm. in one hour, and the Kline exclusion test was negative. The blood serum agglutinated B. tularense 1 : 100. When the blood test was repeated five weeks after the onset of the illness the agglutination titer had risen to 1 : 320. Examination of the hand disclosed a small papular lesion covered with a brown crust. The left epitrochlear lymph node was enlarged; the overlying skin was purplish red, and was firmly attached to the underlying tissue.

We were unable to elicit from our patient a history of exposure to rabbits or fowl, but further questioning disclosed that the family cat had limped for several weeks, and that there was a healing ulceration of the skin on the left hind leg. It was the habit of this patient to fondle his pet as it reposed on his lap. The cat was obtained for examination. It did not appear to be ill; the healing skin lesion was present. The cat's blood serum agglutinated B. tularense 1 : 360.

The patient was given sulfanilamide because of the persisting low-grade fever and lymphadenopathy. He received 165 grains over a period of three days, when the drug was discontinued because of nausea and vomiting. The blood sulfanilamide level had reached 5.9 mgm. per 100 c.c., but there was no apparent improvement in the condition of the patient during this short period of treatment. The left epitrochlear lymph node remained large and progressively became tender and fluctuant, with increased redness and heat. In the fifth week the abscessed node pointed by rupturing through its capsule. We incised and drained the abscess of several ounces of thick yellow-white purulent material. Culture was sterile. The incision drained for three weeks, and the patient was not restored to health for a period of eight months from the onset of his illness.

CASE 2

A two-year-old white boy was bitten on the left cheek by a domestic cat on October 15, 1940, while visiting on his grandparents' farm not far from Detroit. The boy became ill with nausea, vomiting, and fever several days after he was bitten. The lymph nodes of the left cervical region were enlarged and tender. There was anorexia followed by weight loss, and the boy's color and health were poor for several weeks. The wound was cleansed by the mother. A physician was first consulted about December 15, 1940, and he lanced a deep abscess of the left face and drained the purulent material. No culture was taken at the time.

This boy was brought to the Surgical Clinic of Dr. R. D. McClure on January 21, 1941. He was not acutely ill, but there was an indurated swollen area just below the left malar prominence. The tooth marks made by the cat were visible, and at the lower margin of the scar, where the teeth had lacerated and punctured the skin, the area was covered by a brown crust of dried serum. The left cervical lymph nodes were enlarged and tender. Moderate pressure on the boy's cheek caused yellow serum to exude; culture was negative.

The blood count was normal, but the patient's blood serum agglutinated B. tularense 1 : 200 with Mulford antigen.

The cat that bit the boy was brought to the hospital on January 28, 1941. It did not appear to be ill. Its blood serum agglutinated B. tularense 1 : 50 with Mulford antigen. Its tissues, at necropsy, were negative for gross and microscopic tularemic lesions.

CASE 3

A white female, age 15, a student, was brought to the Henry Ford Hospital to the medical service of Dr. R. H. Durham. She had noticed a tender swelling in the left axilla, which had insidiously appeared some four to six weeks before. Although she was unaware of it, her temperature was elevated to 99.4 degrees. When she was examined there was found in the anterior superior portion of the left axilla a single tender, enlarged lymph node approximately 3 cm. in diameter. The erythrocyte count was 4,860,000, with 13.1 grams (84 per cent) hemoglobin. The leucocyte count was 7,000, with 64 per cent polymorphonuclear cells.

On December 30, 1940, four days after the examination, the gland

was removed for biopsy. The pathologist reported the presence of chronic granuloma, probably tularemia. With this report in mind the patient's history was rechecked for possible contacts with that organism. It was learned that the family cat was "mean," and for some weeks had scratched and bitten members of the family. The patient recalled having had a slight abrasion some weeks before on the left index finger, where the cat had bitten her, but it had healed before we saw her.

The patient's blood serum was found to agglutinate B. tularense 1:50. After the biopsy there was a gradual rise in the leucocyte count until at the end of one week it was 15,950, with 85 per cent polymorphonuclear cells. The temperature continued to rise until it reached 105 degrees. Symptoms were unaffected by administration of 300 grains of sulfanilamide over a period of five days. The blood sulfanilamide level reached 5.1 mgm. per 100 c.c. before the drug was discontinued because of symptoms of intolerance. She became nauseated and vomited frequently, and there were a few erythrocytes in the urine.

The patient's serum agglutination titer had risen to 1:100 with Mulford antigen. She was extremely ill. By January 11, 1941, the temperature was 105.2 degrees, with pulse 140 beats per minute, and the leucocyte count was 16,000. She was given immune serum in the form of a plasma transfusion, 200 c.c. from a recently recovered tularemia patient who had an agglutination titer of 1:5,000 with Mulford antigen at the time the blood was drawn. She was also given 30 c.c. of antitularemic goat serum, which we had just received from Dr. Lee Foshay. She showed striking improvement by the morning of January 12, 1941. The temperature and pulse returned to normal by that afternoon, and there was no further rise. She continued to improve and left the hospital on the twentieth day, at which time her blood serum agglutinated B. tularense 1:1,000.

Two other children from the same family had contact with the cat and were scratched or bitten. One had an agglutination titer of 1:50 with B. tularense; the other had a negative blood test, but there was slight enlargement of the axillary lymph nodes. Both remained well.

We had the family cat brought in for examination. Its blood serum did not agglutinate B. tularense. We did an autopsy, and tissues examined were negative for gross and microscopic tularemic

lesions. The patient's family lived in a suburban community where the cat could hunt rabbits or other rodents in the near-by fields. It was known that the cat had caught small rabbits and could well have been contaminated with B. tularense, but at the same time remained free of infection.

It is significant that the three patients all lived in rural communities where the family pets had ample opportunity to hunt for rodents in fields near the home. The cats in question were all large and capable of hunting rabbits.

SUSCEPTIBILITY OF THE DOMESTIC CAT TO INFECTION

As early as 1911 McCoy and Chapin (2) noted that the domestic cat was susceptible to the plaguelike disease which they were investigating at the time and which in the following year was attributed to the organism named B. tularense. Cats were noticed with buboes from spontaneous or natural infection. They inoculated five cats with a strong emulsion of a 48-hour-agar culture; one cat died on the eighth day, and four developed buboes and ulcerations. The next year the same workers inoculated four cats subcutaneously with large doses of an emulsion made from the liver of a guinea pig dead of tularemia (3). The cats remained well while the control guinea pig died.

Simpson (7, 1929), after reviewing the experimental work of Wherry, Green, Wade and Hanson, and Francis regarding the susceptibility of the domestic cat to infection with B. tularense, concluded that it was mildly susceptible.

TULAREMIA IN MAN AFTER CONTACT WITH CATS

There are several reported instances of tularemia in man due to scratches or bites by cats. Collins (1, 1933) reported ulceroglandular tularemia in a man fourteen days after the bite of a six-month-old kitten. The patient's blood serum agglutinated B. tularense 1 : 1,280, whereas the cat's blood serum agglutinated the organism 1 : 80.

Rudesill (6, 1937) reported tularemia in a woman who had been bitten by a cat or one of its kittens. The mother cat had fed on a dead rabbit. On the thirteenth day the patient's blood serum agglutinated B. tularense 1 : 80; on the seventeenth day it was 1 : 640. The woman recovered after an illness of two months. The mother cat survived, but the kittens died.

The Public Health Bulletin of April, 1940 (5), reported a total of thirteen persons to date with tularemia after contact with cats, two having been scratched and eleven having been bitten by them. This paper reports three cases after contact with domestic cats.

SUMMARY

1. Three patients with ulceroglandular tularemia after contact with pet house cats have been presented. All three patients recovered.

2. The domestic cat is susceptible to infection with B. tularense and may cause the disease in human beings. Such a source of infection should not be overlooked, especially if the cat is in a suburban community where it is free to hunt rabbits or other rodents in nearby fields.

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THE USE OF PLASMAPHERESIS EXPERIMENTS AS AN INDEX OF THE EFFICACY OF BLOOD SUBSTITUTES

KENNETH W. WARREN AND HENRY N. HARKINS

INTRODUCTION

IN WARTIME the treatment of shock is a subject of prime importance. Such treatment must be founded on an accurate scientific knowledge of the basic physiologic and pathologic changes that occur in shock. The development of this knowledge has been hampered in the past because of the lack of an adequate method of quantitative production of shock. Without such a method the estimation of the value of various blood substitutes was not accurate. Experiments were carried out to see whether the use of animals from which large amounts of plasma had been removed by plasmapheresis might not help in the quantitative appraisal of certain of the most commonly used substitutes.

In the present study a comparison is made of the effects of saline solution and of Locke's solution in preventing shock in animals on which plasmapheresis experiments were performed.

STANDARD METHODS OF PLASMAPHERESIS

In 1914 Abel, Rowntree, and Turner (1) described a method of plasma depletion that was effected at intervals over a period of hours or even days. The technic consisted in bleeding dogs a variable *decrement* of their total blood volume and in centrifuging the blood and separating the cells, which were resuspended in Ringer-Locke's solution and reinjected. This operation was repeated several times during the experiment. The method, though applicable to acute plasmapheresis, is better adapted to chronic plasma removal.

Whipple (4, 5), following the method of Morawitz, employed washed donor cells suspended in Locke's solution or in fresh dog serum, and utilized the principle of synchronized bleeding and infusion. The animal was bled from the femoral artery, and the blood substitute

was infused simultaneously into the femoral vein. This continuous operation was carried to the desired limit or to the point imposed by the tolerance of the animal. The advantages of this method are the rapidity with which the exchange can be made and the maintenance of a constant blood volume and uniform cell concentration.

Amberson's method (2, 3) consists in alternate bleeding and injection of cell-substitute mixture through a single cannula, inserted into a carotid artery. The cells are collected from several donor animals, washed three times with Ringer-Locke's solution, and suspended in 6 per cent acacia-saline mixture just prior to the injection. In cats this author removes and injects 50 cubic centimeters at a time; in dogs the amount is 100 cubic centimeters. The infusion is backward toward the heart under pressure. This method has been exceedingly successful in the hands of its originator.

AUTHORS' TECHNIC

The animals used were small dogs of random breed, maintained on a mixed diet. In the group of experiments reported in this communication we employed morphine narcosis, supplemented by local infiltration of 2 per cent novocaine in the femoral region on one side. Through a small skin incision the femoral artery and vein were exposed and cannulated separately. The animal was bled from the artery into a graduated flask. Simultaneously a suspension of corpuscles was injected into the femoral vein by force of gravity from a graduated cylinder. In one group of animals the corpuscles were suspended in normal saline solution and in the other group in modified Locke's solution. The composition of the modified Locke's solution was: sodium chloride, 0.9 per cent; potassium chloride, 0.04 per cent; sodium bicarbonate, 0.02 per cent. The cell substitute mixture contained about 40 per cent packed corpuscles by volume. The donor cells were obtained by bleeding one or more dogs. The corpuscles were washed twice with normal saline without strict aseptic precautions being observed.

The rate of exchange was rapid and usually required from 10 to 25 minutes. The amount of fluid withdrawn ranged from 55 cubic centimeters per kilogram to 130 cubic centimeters per kilogram. Samples of blood were collected from the arterial cannula at the beginning and at the end of the exchange. The cannulae were removed, and the incision was closed with interrupted silk skin

sutures. Plasma proteins were determined by the Kjeldahl method. The clinical condition of all animals was followed closely, and autopsies were performed on all that expired.

COMPARISON OF THE EFFICACY OF NORMAL SALINE SOLUTION AND LOCKE'S SOLUTION IN PREVENTING SHOCK

After considerable experimentation with the three methods listed above fifteen dogs were used for a series of plasmapheresis experiments in which the Whipple technic, as just described, was employed.

Normal Saline Solution

In a series of seven dogs normal saline solution was substituted for the removed plasma. Two of the dogs lived more than seven days, and the plasma proteins were reduced to an average level of 2.6 gm. per cent after an average exchange of 66 c.c. per kgm. body weight. The average final plasma protein level of the four dogs that survived the period of shock was 3.0 gm. per cent, and the average exchange was 62 c.c. per kgm. body weight. Only one dog had a final plasma protein level of 2.0 gm. per cent or less, and it lived for only 12 to 24 hours (see Table I A).

Locke's Solution [1]

In a series of seven dogs Locke's solution was substituted for the removed plasma. Three of the dogs lived more than seven days, and the plasma proteins were reduced to an average level of 2.0 gm. per cent after an average exchange of 96 c.c. per kgm. body weight. The average final plasma protein level of the four surviving dogs in this series was 2.1 gm. per cent, and the average exchange was 88 c.c. per kgm. of body weight. Thus the final protein level of the group treated with Locke's solution averages 0.6 gm. per cent lower than in the saline-treated series, or 0.9 gm. per cent lower if only the surviving dogs of each series are considered. The extent of the drop from the initial values is not so favorable, however, to the Locke's solution, since it averaged only 0.2 gm. per cent more than saline-treated series. On the other hand, in five of the dogs treated with Locke's solution the lowest level of plasma proteins attained was

[1] Locke's solution is usually composed of sodium chloride, 0.9; calcium chloride, 0.024; potassium chloride, 0.042; sodium bicarbonate, 0.03; dextrose, 0.1; and distilled water, 100.0.

TABLE I

REDUCTION OF PLASMA PROTEINS BY PLASMAPHERESIS WITH SUBSTITUTION OF REMOVED PLASMA BY (A) NORMAL SALINE SOLUTION AND (B) LOCKE'S SOLUTION

A. NORMAL SALINE SOLUTION

Experiment	Dog weight kgm.	Exchange c.c./kgm.	Plasma proteins gm. per cent		Survival time
			Initial	Final	
1	7.5	66	5.4	2.8	2 hours
2	9.0	78	5.0	2.2	12–24 hours
3	9.0	72	4.5	1.2	12–24 hours
4	11.0	55	..	3.1	7 days*
5	8.5	71	4.7	3.0	5 days*
6	11.5	61	6.3	2.8	24 hours†
7	9.8	61	6.2	3.1	7 days
Average..	9.5	66	5.3	2.6	

* Accidental death † Distemper

B. LOCKE'S SOLUTION

Experiment	Dog weight kgm.	Exchange c.c./kgm.	Initial	Final	Survival time
1	5.4	130	3.4	1.1	2 hours
2	11.4	72	6.2	3.1	12–24 hours
3	5.2	121	5.1	1.5	3 hours
4	11.4	72	4.8	2.0	5 days ‡
5	7.5	86	5.0	2.3	7 days
6	9.3	96	5.4	2.0	7 days
7	8.2	97	4.5	2.0	7 days
Average..	8.3	96	4.9	2.0	

‡ Infected leg

2.0 gm. per cent or less, and three of these animals lived five days or more (see Table IB).

COMMENT

Technical problems make successful extensive experiments difficult. In the small series studied Locke's solution seemed to have a definite advantage over normal saline solution in preventing shock, despite very low levels of the plasma proteins, and in preserving the life of the animals. The animals could stand a moderate exchange of crystalloid solution for plasma with little effect. When the end point was reached, the animals would quite rapidly become listless, the

respirations would be shallow, and the bleeding rate from an arterial cannula would decrease. For each solution tested this end point would be more or less constant.

On the basis of these experiments evidence is advanced for the superiority of Locke's solution over normal saline solution in the prevention of shock due to plasmapheresis. Whether this superiority would apply to shock from other causes, no conclusions can be drawn. Further experiments are planned to test the relative merits of other blood substitutes by their action in plasmapheresis experiments.

CONCLUSIONS

1. Dogs treated with Locke's solution tolerate more extensive plasmapheresis than those treated with normal saline solution, as measured by both the amount of fluid exchanged per kilogram of body weight and the final plasma protein level.

2. The use of such experiments offers an additional method of quantitative estimation of the efficacy of blood substitutes. The technical difficulties limit the number of experiments that can easily be performed and hence diminish the practical value of this procedure in comparing blood substitutes.

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PHILOSOPHY

JOHN FISKE AND HIS COSMIC PHILOSOPHY

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THE contributions of John Fiske (Edmund Fisk Green) to American thought deserve reëxamination today, one hundred years after his birth, primarily because of the great influence he exerted on the shaping of the modern mind. During the latter half of the nineteenth century the widespread interest in Darwinism, with its many and varied philosophical and religious implications, raised issues over which the best minds of church, study, and laboratory contended. People were perturbed by Darwin, Spencer, Huxley, and the rest, read them with some hesitance, and argued over the application of their ideas to social, ethical, and religious thought. Yet during the four decades from 1859 to 1901 — from Darwin's *Origin of Species* to the death of Fiske — the manner of thinking of the world changed, the intellectual patterns of America quietly shifted from those of the mystic, speculative, and theological mode to the mechanistic, realistic, and materialistic.

The force of the impact of Darwinism and of its interpretation by Spencer and others upon American thought must be emphatically stressed. In philosophy widespread changes came about slowly but certainly. Formal philosophy shifted emphasis. Metaphysics became of less importance, and the relativity of standards and man's new importance in the scale of things and in the social order led to greater activity in the fields of psychology and ethics, studies modified and conditioned by science. More important were the emphasis placed upon experimental methodology and the interest in naturalism, both of which filtered into and through all mental activity.[1] American scientists debated the generalizations of Darwin and Spencer as well as the evidence upon which they were based, attempting either to refute wholly or to popularize in more attractive form the Darwinian

[1] See B. J. Loewenberg, "Darwinism Comes to America," *Mississippi Valley Historical Review*, 28 (1941): 339–369, or John Dewey, *The Influence of Darwin on Philosophy* (1910), for complete discussions.

theories of existence and development.[2] In theology the implications of Darwinism created as much disturbance, for its denial of orthodox doctrines, supported by scientific evidence, changed the whole relationship of man to God, of man to nature, and of God to the universe. By no equivocation could a thinker escape the challenge; every philosopher, scientist, and theologian had to declare agreement or dissent, at least with respect to the general principles of Darwinism, and by 1890 evolution in a variety of forms — from the skepticism of Huxley to the softer Christian theories of Drummond — had become thoroughly naturalized in America. John Fiske was a catalyst in the process, and his importance lies in the fact that he was among the first, and certainly the most widely respected, interpreters of the new science in America. He was its prime apologist and philosopher, called by a modern historian "one of the most important intellectual influences in the last quarter of the nineteenth century." [3]

John Fiske's work divides itself naturally into two related parts, both of which stemmed from his scientific interests. His early and middle years were given over to a defense of Darwinism, to the explanation and dissemination of the philosophical doctrines of Herbert Spencer, and to the application to the various branches of knowledge of the techniques absorbed from his study of contemporary science. In addition to his propagation of the new scientific thought he concerned himself with its philosophic and religious implications, attempting to provide a religious background for the scientific materialism which he himself had helped to explain and extend. Then, after 1875, he became increasingly interested in historical writing, in applying the Darwinian and Spencerian principles to history in order to reveal the evolutionary development of social and political institutions. He was therefore not only the philosopher of Darwinism but the historian of early America. Standing at the threshold of the period of the great transition, he centered his work about three focal points, all parts of an educative process designed to correlate old belief and new science, to spread among the American people the facts and the implications of the intellectual revolution then sweeping the nation.

[2] B. J. Loewenberg, "The Reaction of American Scientists to Darwinism," *American Historical Review*, 38 (1933): 687–702, gives an excellent account of the controversy.

[3] Adams, James Truslow, in *The Dictionary of American Biography*.

First of all, Fiske intended to explain the work of Darwin and Spencer simply as scientists, to acquaint his readers with the actual evidence upon which the theories of natural selection, survival of the fittest, and the origin of species were founded. Although a relatively minor part of his work, this purely scientific element bulks fairly large in his writings, as parts of the *Outlines of Cosmic Philosophy* (1874), *Darwinism and Other Essays* (1879), *Excursions of an Evolutionist* (1884), *A Century of Science* (1899), and other volumes attest. Next it was Fiske's aim to show in the development of language, society, and American political and social institutions the working out of evolutionary laws. More than half of his published volumes deal with American history of the colonial and revolutionary periods, for he was interested in discovering the origin and emergence of the distinctive political and social laws of the United States. His intention was to present "the drama of American civilization . . . as an evolutionary development from antecedent causes and of great significance to the future civilization of the world."[4] Particularly good examples of his historiographical approach are his *Civil Government in the United States* (1890) and *The Beginnings of New England* (1902).[5] Yet Fiske's historical writings, popular as they were, have suffered with the passage of time and by themselves constitute little claim for recognition of his intellectual eminence and importance.[6]

The third problem to which Fiske devoted his life was that of providing for the Christian religion a scientific foundation in the work of Darwin and Spencer, of resolving the seeming conflict between religion and science, of teaching mankind the proper method of aligning scientific thought with the existing scheme of things, and of disassociating in the popular mind the agnostic positivism of Comte from the theism of Spencer. Fiske in early life came to the conclusion that Christianity was undergoing a purification through

[4] See John Spencer Clark's authoritative biography, *John Fiske* (New York, 1917), II: 456. Fiske said in the preface to his *American Political Ideas:* "The government of the United States is not the result of a special creation but of evolution."

[5] In the first of these books Fiske spends more than one seventh of his text in a discussion of Roman and English backgrounds, and in the second he traces the evolution of the New England township system back to the Greek *ecclesia* and the Roman *comitium*.

[6] For competent modern estimates of Fiske's historical work see J. B. Sanders' essay in *The Marcus W. Jernegan Essays in American Historiography* (ed. W. T. Hutchinson, 1937) and Michael Kraus, *A History of American History* (1937).

science, being stripped of inconsistencies, superstitions, and traditional accretions, and was being brought back to its original dignity and purity. With Darwinian biology he felt, ". . . we rise to a higher view of the workings of God and the nature of man than was ever attainable before."[7] He repeated many times his belief that science and religion were reciprocally strengthening, that from Darwinism man gained a cosmic optimism and an unshakable belief in God.[8] His great contribution to the stream of ideas was therefore a philosophical and religious one, for only through Fiske did America discover that a man could be both Darwinian and a worshipper of God, that science was but "the modern phase of the feeling which led the ancient to fall upon his knees and adore . . . the Invisible Power whereof the infinite web of phenomena is but the visible garment."[9] Finally, after rejecting traditional orthodox Christianity, Fiske offered, not as a substitute but rather as an extension of it, a religious philosophy fitted to the needs of a new and scientific age — Cosmic Theism. The central question of religious faith was, he believed, What must the rational mind postulate as the Ultimate First Cause behind all phenomena, and what must be its methods of manifestation or revelation to the human mind?[10] This question lay beneath all Fiske's subsequent philosophic and religious thought, and when in the year 1860 Spencer broke over his mind like a great light, he dedicated the rest of his life to working out the answer in Cosmic Theism.

[7] *The Destiny of Man*, p. 14.

[8] See Fiske's essay, presented to the Concord School of Philosophy, *The Idea of God as Affected by Modern Knowledge;* his review of Draper's *History of the Conflict of Science and Philosophy* (1875), reprinted in *The Unseen World*, pp. 182–196; the essay "Darwin on Science and Religion," reprinted in *The Unseen World;* his "Darwinism Verified" and his review of Büchner, reprinted in *Darwinism and Other Essays*. Summarizing his views, Fiske stated in *The Unseen World* (p. 3): "In reality there has never been any conflict between religion and science, nor is any reconciliation called for where harmony has always existed. The real historical conflict, which has thus been curiously misnamed, has been the conflict between the more crude opinions belonging to the science of an earlier age and the less crude opinions belonging to the science of a later age."

[9] *Outlines of Cosmic Philosophy*, I:417. Fiske's contemporary, Henry Adams, found in physics little of the hope for human progress that Fiske discovered in biology. In his *Letter to Teachers of American History* (1910) Adams urged the application to history of the second law of thermodynamics — the universal tendency to a dissipation of energy — in order to refute the theory of progress toward perfection.

[10] Clark, *op. cit.*, I:122–125.

Fiske, having rejected orthodox Christianity at the age of seventeen, went to Harvard to begin his collegiate career in a rebellious mood. Two major intellectual events stand out in his college years. He met Emerson, and he discovered Spencer. In his sophomore year he made the pilgrimage to Concord to visit the graying sage, pronouncing him "the greatest man I ever saw. . . . None can be compared with him for depth, for scholarship, and for attractiveness." [11] Equally important was the discovery he made in June, 1860, at Ticknor and Fields' Boston bookstore, where he found a copy of the prospectus written by Herbert Spencer explaining his projected series of philosophical books on evolution. His acquaintance with Spencer marked the opening of his mature intellectual life, and almost from the beginning of his reading of the *First Principles*, when he had once mastered the scientific theory behind it, he spent his time explaining Spencer's ideas, applying them to the various branches of knowledge, and finally aligning and correlating them with Christianity.

Fiske's first step was explanatory. Although he had called himself a "Positivist" in 1860,[12] he had definitely abandoned the position by 1869. His lectures at Harvard during that year, titled "The Positive Philosophy," might better have been named "The Evolutionary Versus the Positive Philosophy," for they were mainly concerned with establishing the superiority of Spencer over Comte. The lectures served to crystallize in his mind the half-systematized ideas of nearly a decade, and the lines of thinking of nearly ten years fell suddenly into a pattern. His three years of lecture and study, he told his mother, ". . . threw a blaze of new light upon the complete harmony between Christianity and the deepest scientific philosophy." [13] The result was the *Outlines of Cosmic Philosophy*.

Fiske's *Cosmic Philosophy*, presented primarily as an appreciation of the system advanced by Spencer, showed some original contributions by Fiske in his explanation of the relationship of Spencer to other thinkers, in his attack on the Positivists, and in his application of Spencer's ideas to social and religious matters. Put in simplest terms, his "cosmic" philosophy was Spencerian evolutionary

[11] *Ibid.*, I: 214. Emerson talked to the young man of Voltaire, Buckle, Carlyle, and others "in a deep bass voice."

[12] *Ibid.*, I: 139, 141.

[13] Abbott, Lyman, *Studies of My Contemporaries* (1922), p. 91.

philosophy as it related to God, man, and the universe. For the first time the public was presented with evolution and its ramifications; about that principle, as Fiske saw it, was growing a philosophical system that took evolution out of science into the realm of theology. He felt that his book was deeply religious. He was certain, too, that it held the germ of a new type of Christianity, which he called, in the concluding chapter, Cosmic Theism — a term by which he meant to denote the religious phase of the philosophy based upon the doctrine of evolution.[14] He did not intend to found a new religion or to destroy utterly the old Christianity, but rather it was his purpose to inaugurate a rebirth of Christian belief by integrating science and faith, illustrating how evolution added deeper meanings to religious belief, and establishing an intelligent and enduring alliance of the two.[15] The bulk of his subsequent work (except his historical writing, a narrower application of the evolutionary hypothesis to a single field) was taken up with the execution of his plan.

An explanation of what Fiske included in the body of principles called Cosmic Theism must begin with what he felt to be the central fact of the universe — the reality of God. As a scientist and as a philosopher he could not by any stretch of the imagination deny the existence of a deity. One must choose, he said, among three possible beliefs — atheism, pantheism, and theism. The atheist's position that "the world of phenomena exists as sufficient unto itself" he found untenable. Pantheism (Fiske included agnosticism in the term), with its postulation that the universe is self-controlled and that beneath the world of phenomena is "an inscrutable essence, a formless void," was likewise unacceptable to him. Therefore theism, the doctrine that the world is "a multiform manifestation of an Omnipresent Energy," remained as the only logical belief.[16] Man-

[14] He explained to his mother: "When my *Cosmic Philosophy* comes out you will see how utterly impossible it is that Christianity should die out; but utterly *inevitable* that it should be metamorphosed . . ." (*ibid.*, p. 92). Cf. the questions of Fiske's contemporary British Darwinian, Samuel Butler: "Does any man of science believe that the present orthodox faith can descend many generations longer without modification? Do I . . . doubt that the main idea underlying the present faith is essentially sound?"

[15] For Fiske's explanation see the chapters titled "The Attitudes of Philosophy" and "Cosmic Theism" in Volume II of the *Outlines of Cosmic Philosophy*. A good summary of his view occurs in "The Idea of God," reprinted in *Studies in Religion*.

[16] *Outlines of Cosmic Philosophy*, I: 6–22.

kind cannot believe otherwise, for inherent in humanity is a "craving for a final cause, the theistic assumption . . ., one of the master facts of the universe."[17] Theism, of course, postulates a First Cause or Deity, which according to Fiske's reasoning must be self-existing, infinite, and absolute.[18] The chief characteristic of the Deity thus conceived is Unity, "a reasonableness in the universe such as had not appeared before. The truth is that the entire modern universe is an immense unit, animated through all its parts by a single principle of life. . . . The presence of God is the one all-pervading fact of life from which there is no escape."[19] Fiske did not, however, rely upon logic alone for proof of the existence of Deity, or Unity; it is but "the legitimate outcome of modern scientific thought to believe in God." Science, and in particular the evolutionary theory of Darwin and Spencer, seemed to him to display the greatest evidence of the existence of God, proof far superior to that offered by traditional Christianity. Because science showed God's hand in all creation, because it proved man to be the result of a universal cosmic process, Fiske affirmed that "of all the implications of the doctrine of evolution in regard to man, I believe the very deepest and strongest to be that which asserts the Everlasting Reality of Religion."[20] Thus the phantom of the hostility between science and religion is exorcised forever, for "from man's origin we gather hints to his destiny, and the study of evolution leads our thoughts through nature to God."[21]

Fiske's definition of God placed him, so far as the question of the divinity of Christ was concerned, with the Unitarians and Transcendentalists. He drew a definite distinction between "the Jesus of history" and "the Christ of dogma." The former, he explained to

[17] *Through Nature to God*, p. 217.

[18] *Outlines of Cosmic Philosophy*, I: 8–10. Fiske later, in *Excursions of an Evolutionist*, added beneficence, believing that evolution proved that "the Eternal Power works for righteousness."

[19] "The Idea of God," *op. cit.*, pp. 101–102 (see note 15).

[20] *Ibid.*, p. 371.

[21] *Through Nature to God*, p. 221. Although Fiske was certain of God's existence and of His manifestation through a scientific study of nature, he did not believe God wholly demonstrable by science alone; man must accept the infinite Deity partly in pure faith. See the *Outlines of Cosmic Philosophy*, II: 470. Borden P. Bowne, in *The Philosophy of Theism* (1887), carried out to its philosophical conclusions, without using science as a basis of proof, Fiske's idea that the multiplicity of the universe implied Unity behind it, and that that Unity was the theistic God of Christianity.

his grandmother, was the noblest character who ever lived, but his personality had been perverted in men's minds by the dogmatists and creed makers.[22] His religious system, with its denial of anthropomorphism and its concept of an infinite, unknowable, and absolute Creator, left no room for a second divinity. Still, the man Jesus remained always to the historically minded Fiske a noble, mysterious, and provocative figure. A projected book, "Jesus of Nazareth and the Founding of Christianity," was in his mind for some years but was never begun.[23]

The inferred position of mankind in relation to God and the universe was to the mind of the nineteenth century one of the most distasteful implications of the evolutionary hypothesis. If man had, as science suggested, a bestial origin, did it not make of him merely a beast of a higher order, no more the object of God's special affection and care than any other creature? Continuing the same line of thought, men asked, What of man's immortal soul — had he any more right to claim immortality than any other animal? In the same fashion the problem of sin and evil, considered in relation to Darwinism, raised difficult questions. If the law of the survival of the fittest, hardly compatible with the Christian spirit, applied to human society as science seemed to infer that it might, what would happen to the traditional concepts of morality and ethics? Fiske set himself to explain away these and other inconsistencies between the new science and the older theology.

To Fiske, after reading Darwin, "man seems now, much more clearly than ever, the chief among God's creatures." Although man rose from animal beginnings, it did not necessarily follow, argued Fiske, that he was to be considered simply the highest development yet found of the animal hierarchy. In the animal, physical variations outbalanced psychical; when the opposite became true, and a brain developed, man definitely outgrew his bestiality and became human.[24] Taken as a whole, he explained, the story of man's evolutionary development seemed much more inspiring and significant

[22] See Fiske's reviews, "The Jesus of History" and "The Christ of Dogma," reprinted in *The Unseen World*, and Clark, *op. cit.*, I: 122. Compare Emerson's early sermons, in A. C. McGiffert, *Young Emerson Speaks* (1938).

[23] Preface to "The Jesus of History," *The Unseen World*, p. 87.

[24] *The Destiny of Man*, pp. 42–44. So did the heliocentric Copernican theory, Fiske pointed out, seem at first to lessen man's importance in the scale of things, yet we have become accustomed to it.

than the commonly accepted orthodox view of his creation. Man was not degraded by his kinship with the lower forms of life in the evolutionary scale, but, instead, was to be considered the ultimate end of God's plan of creation:[25]

> The Darwinian theory shows us distinctly for the first time how the creation and the perfecting of man is the goal toward which Nature's work has all the while been tending. It enlarges tenfold the significance of human life, places it upon an even loftier eminence than poets or prophets have imagined, and makes it seem more than ever the chief object of that creative activity which is manifested in the physical universe.

Concerning the existence of a soul and of a future immortal life, Fiske went beyond scientific proof to base his belief in both on pure faith. Science, he admitted, had certain limitations since it dealt solely with demonstrable and material things, and therefore was of little use in treating of supranatural and extramaterial truths. Mankind did possess a soul, he believed, not merely, as the materialist insisted, "the product of a cunning arrangement of material particles," although its reality could not be made a matter of laboratory proof.[26] Life beyond the grave was likewise incapable of scientific demonstration, but since it is true, he pointed out, that evolutionary development must have a goal as well as a beginning, the opinion that the human race developed from an animal ancestry and has not yet reached its goal gives us the right to anticipate a further development in a future life. "Therefore," concluded Fiske, "for my own part I believe in the immortality of the soul, not in the sense in which I accept demonstrable truths of science, but as a supreme act of faith in the reasonableness of God's work." [27]

The place of sin and evil in the theology of cosmism outlined by Fiske served to remove much of the objectionable aura of immorality surrounding the application of Darwinism to ethics and morality. Evil exists through God's plan, said Fiske, because life must have an "element of antagonism"; God is the creator of evil, for in a moral world a knowledge of evil is indispensable:[28]

[25] *Ibid.*, p. 14.

[26] *Ibid.*, pp. 27, 76. He repeated the argument in *The Unseen World* and in "Life Everlasting," reprinted in *Studies in Religion.*

[27] *Ibid.*, p. 82. He said, in *The Unseen World* (p. 58), that, though ". . . we cannot adduce any proof of the possibility of an unmaterial, psychical world by materialistic means, our failure to do so does not raise the slightest presumption that such a world is impossible."

[28] *Through Nature to God*, pp. 251–252.

We do not find that evil has been interpolated into the universe from without; we find on the contrary that it is an indispensable part of the dramatic whole. . . . What would have been the moral value or significance of a race of human beings ignorant of sin, and doing beneficent acts with no more consciousness or volition than the deftly contrived machine that picks up raw material at one end and turns out some finished product at the other?

Evil, as he defined it, meant violation of natural and therefore Divine law. To live in conformity with Nature's law is to live religiously and morally: "From the scientific point of view, sin is a willful violation of a law of nature, or — to speak in terms of the theory of evolution — it is a course of thought or action, willfully pursued, which tends to throw the individual out of balance with his environment, and thus to detract from his physical or moral completeness of life." [29] The medieval saint sought righteousness in attempting to become like his highest concrete conception of excellence embodied in Christ; the scientific theist formulates his feeling toward morality in an attempt to live in entire conformity with the requirements of nature. The moral ideal of the scientist differs from that of the saint only in his avoidance of an anthropomorphic symbol to express it.

But the acceptance of the theory of morality as absolute conformity with nature's laws carried with it certain difficulties. Since Darwin had shown that an incontrovertible law of nature was that of the survival of the fittest, did not Fiske's chain of logic prove that men must and should live by it? By way of answer Fiske warned against hasty interpretations of the struggle for existence; God's ways are not fully understood by men, and perhaps "could we raise the veil that enshrouds eternal truth, we should see that behind nature's cruelest works there are secret springs of divinest tenderness and love." [30] It is totally at variance with the inferences of evolution to suppose that, because mankind developed from animal origins, he must remain an animal and continue to live on the animal level. As physical forms have developed from lower to higher, so has morality. Man has advanced beyond the stage where he is morally and naturally bound to kill his weaker brother, and the survival of the fittest is a rule which no longer holds on the level of humanity. "The wholesale destruction of life, which has heretofore characterized evolution ever since life began . . . must presently come

[29] *Outlines of Cosmic Philosophy*, II: 465.
[30] *Through Nature to God*, p. 258.

to an end in the case of the chief of God's creatures. In the lower regions of organic life it must go on, but as a determining factor in the highest work of evolution it will disappear."[31] The lower levels of life lack a developed morality or conscience. On the higher levels morality emerges, and in man "the moral becomes dominant." When the moral stage is reached, we have in man a creature different in kind from his predecessors, fit for a life of progress, for a closer and closer communion with God. Evil therefore is only a brute inheritance, "the characteristic of the lower state of living as looked on from the higher state."[32] Supporting his theory of man's moral evolution with scientific proof, Fiske pointed out that man possesses a certain inherent altruism lacking in animals. As intelligence grows in the scale of creation, he said, the period of infancy lengthens, requiring more and longer care of the infant by the parents. We must postulate, therefore, the existence of an increasing degree of selflessness and benevolence in the adult, as he rises higher in the scale. Since the period of infancy is shortest in the lower brackets of life, longer in the higher animals, and longest of all in man, we have not only scientific proof that nature is not innately cruel, but evidence to show that mankind possesses the greatest amount of inherent altruism in all creation. On the human level life in conformity with the laws of nature is life in perfect accord with the Christian ethic, for it emphasizes not the survival of the fittest, but the brotherhood of man, not the atavistic brute urge of cruelty, but the goodness and kindness of humanity.[33] Fiske continued the

[31] *The Destiny of Man*, p. 67. Emerson said in the essay "War" (*Miscellanies*, p. 193): "At a certain stage of his progress, the man fights, if he be of sound mind and body. At a certain higher stage he makes no offensive demonstration. . . . At a still higher stage, he comes into the region of holiness; passion has passed away from him; his warlike nature is all converted into an active medicinal principle . . ., engaged, throughout his being, no longer to the service of an individual but to the common soul of all men." The British Darwinian Samuel Butler likewise accepted the survival-of-the-fittest theory, but not its implications. As an alternative to chance as the motivating power behind evolution he proposed a "creative urge" somewhat similar to Fiske's "creative activity" and Henri Bergson's "vital impetus." See Butler's *Evolution Old and New* (1879).

[32] *Through Nature to God*, pp. 262–265.

[33] This theory of the intellectual and religious significance of the lengthened period of infancy was Fiske's sole contribution to Spencerian philosophy. First stated in the *Outlines of Cosmic Philosophy*, it was developed further in *Through Nature to God*, in *The Destiny of Man*, and particularly in the essay *The Meaning of Infancy*. Fiske was first struck by the idea during his lectures in 1871 and 1872,

line of thought; if evolution has carried man thus far from the brute, it may carry him further to that ideal plane of existence whereon evil and sin no longer exist: "From the general analogies furnished in the process of evolution, we are entitled to hope that, as it approaches its goal and man comes nearer to God, the fact of evil will lapse into a mere memory." [34]

Science gives us, then, "the lost clue to the Sermon on the Mount" and shows us in the future the Christian level of life on which the beast inheritance of sin is no longer existent. The prophet of science becomes the prophet of hope, for the law of evolution proves that man is undergoing modifications that must eventually end in completeness. The progression of the human race upward is not by grace of a capricious God, but through the careful plan of a scientific Deity evinced in and proved by evolution, a plan underlying the whole of organic creation. "We may look forward," said Fiske, "to the time when in the truest sense the kingdom of the world shall become the kingdom of Christ. . . . The future is lighted for us with the radiant colours of hope." [35]

Fiske's Cosmic Theism encompassed, then, a belief in an absolute, infinite, independent, and benevolent God; in human progress upward through evolution; in the immortality of the soul; in the manifestation of the Deity in the natural world and its perception through the scientific study of nature; and in the existence of evil as an "antagonistic element," but in man's ability to escape evil by life in accord with natural law, which was ultimately beneficent. His modifications of traditional Christianity consisted mainly of a denial of the Biblical version of creation, his rejection of anthropomorphism and the orthodox beliefs of revelation, and the refusal to accept the divinity of Christ. The importance of Cosmic Theism lay, however, as Fiske realized, in the substitution of scientific for theological symbols in religion. To him revelation of God came from biology

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and mentioned it to Spencer in his early correspondence with the Englishman. Spencer thought it "a grand idea." See Clark, *op. cit.*, I: 471.

[34] *Studies in Religion*, p. 266.

[35] *The Destiny of Man*, pp. 74–77. His essays *The Evolution of Society, Illustrations and Criticisms*, and *The Conditions of Progress* give a complete treatment of his idea of progress. Tough-minded Orestes Brownson, however, failed to perceive in Darwinism any such glowing hope of progress. To him evolution merely proved the transformation of one species into another, not necessarily progressively. See *Literary, Scientific, and Political Views*, p. 138.

and physiology as it had come to his ancestors from the Scriptures.[36] Spencer and the English Darwinians had already exalted the doctrine of progress into a cosmic law, but Fiske, in the best and oldest New England tradition, provided a full theological background for the new science, carrying on the Unitarian movement of Emerson and Parker, bridging the gap between science and religion, proving that the plans of God perceptible behind the evolutionary development of man were progressive, beneficent, and purposeful.[37] He refused the agnosticism of the Englishmen, and instead saw in evolution the final proof of the existence of a vast Creative Mind whose cosmic plan was slowly unfolding in the history of humanity. By perceiving and revealing the spiritual and religious aspects of the scientific philosophies Fiske was instrumental in softening the shock of the impact of science upon orthodoxy, acting as coördinator, interpreter, and adjuster between old and new. He was a skeptic, and he attacked orthodoxy in no uncertain terms, but as he destroyed he also built. He gave new meaning to the older transcendentalist concept of an immanent God, made the universe theistic, and natural law purposive and progressive. Evolution, he showed, was merely "God's way of doing things," and when his friend Lyman Abbott took his ideas into the pulpit, Christianity, it seemed, was made secure.[38]

Fiske's greatest debt was naturally enough to his idol Herbert Spencer, for from him he drew not only the scientific theories upon which he built his Cosmic Theism, but the majority of his inferences and the greater part of his inspiration. His statement to Spencer, written at the age of twenty-two, held literally true throughout his life:[39] "The influence of your writings is apparent alike in every line of my writings and every sentence of my conversation; so inextricably have they become intertwined with my own thinking that frequently, on making a new generalization, I scarcely know whether to credit myself with it or not." Yet Fiske was too much the New Englander and too much the child of Puritanism to escape the religious

[36] *Outlines of Cosmic Philosophy*, II: 453.

[37] Fiske felt that "Spencer's work on the side of religion will be seen to be no less important than his work on the side of science, when once its religious implications shall have been fully and consistently unfolded" (*Excursions of an Evolutionist*, p. 276). William James, like Fiske, rejected Comte's Positivism and found inspiration instead in Spencer's reflection of Darwin; see H. G. Townsend, *Philosophical Ideas in the United States* (1934), for a discussion.

[38] See Lyman Abbott's *The Theology of an Evolutionist* (1897).

[39] Clark, *op. cit.*, I: 294.

awareness that characterized his heritage. The influence of Emerson upon his intellectual growth, an influence of spirit rather than of fact but a major one nonetheless, must be noted. Fiske had Emerson's books in his library at the age of seventeen, and read them for the rest of his years as a "tonic to the thinking mind." He liked to dip into Emerson frequently, he told his biographer, "because he found him so impregnated with the evolutionary idea, and his insights gave . . . food for thought."[40] Emerson, too, was a rebel against orthodoxy, a searcher after a bridge between science and religion. Emerson, with his acquaintance with the nascent evolutionary thought of the first half of the nineteenth century, concerned himself in much the same way with the juncture of science and religion, attempting, as did Fiske, to work science into the existing scheme of things. Fiske, more the scientist and less the philosopher, provided in his own way that link between nature and Deity for which the elder man searched.[41] Fiske called his Deity "the Invisible Power," "the Ultimate First Cause," "Omnipresent Energy," "Unity," "the Source of Moral Law," "Creative Activity," "Infinite Power," and simply God. Emerson named his "Oversoul," "Law Alive," "Conscious Law" — in effect the two concepts were the same.[42] Fiske's Cosmic Theism represented Transcendentalism plus science, a blend of the religious-philosophical thought of Emerson with the cosmic science of Darwin and Spencer, the religion of New England as it appeared from the laboratory in the later nineteenth century.

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[40] Clark, *op. cit.*, II: 476. At one of his last visits to Fiske, Clark found him deeply immersed in Emerson, and Fiske's subsequent discussion (pp. 478–482) is highly illuminating.

[41] For a complete survey of Emerson's use of scientific thought see H. H. Clark, "Emerson and Science," *Philological Quarterly*, 10 (1931): 225–260. Fiske thought that had Emerson been a younger man — he was nearly sixty when *The Origin of Species* appeared — he might have become the great philosopher of Darwinism.

[42] Emerson, like Fiske, rejected an anthropomorphic conception of the Deity. "I say that I cannot find, when I explore my own consciousness, any truth in saying that God is a person, but the reverse. . . . I deny personality to God because it is too little, not too much." (*Journals*, March 5, 1838.)

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